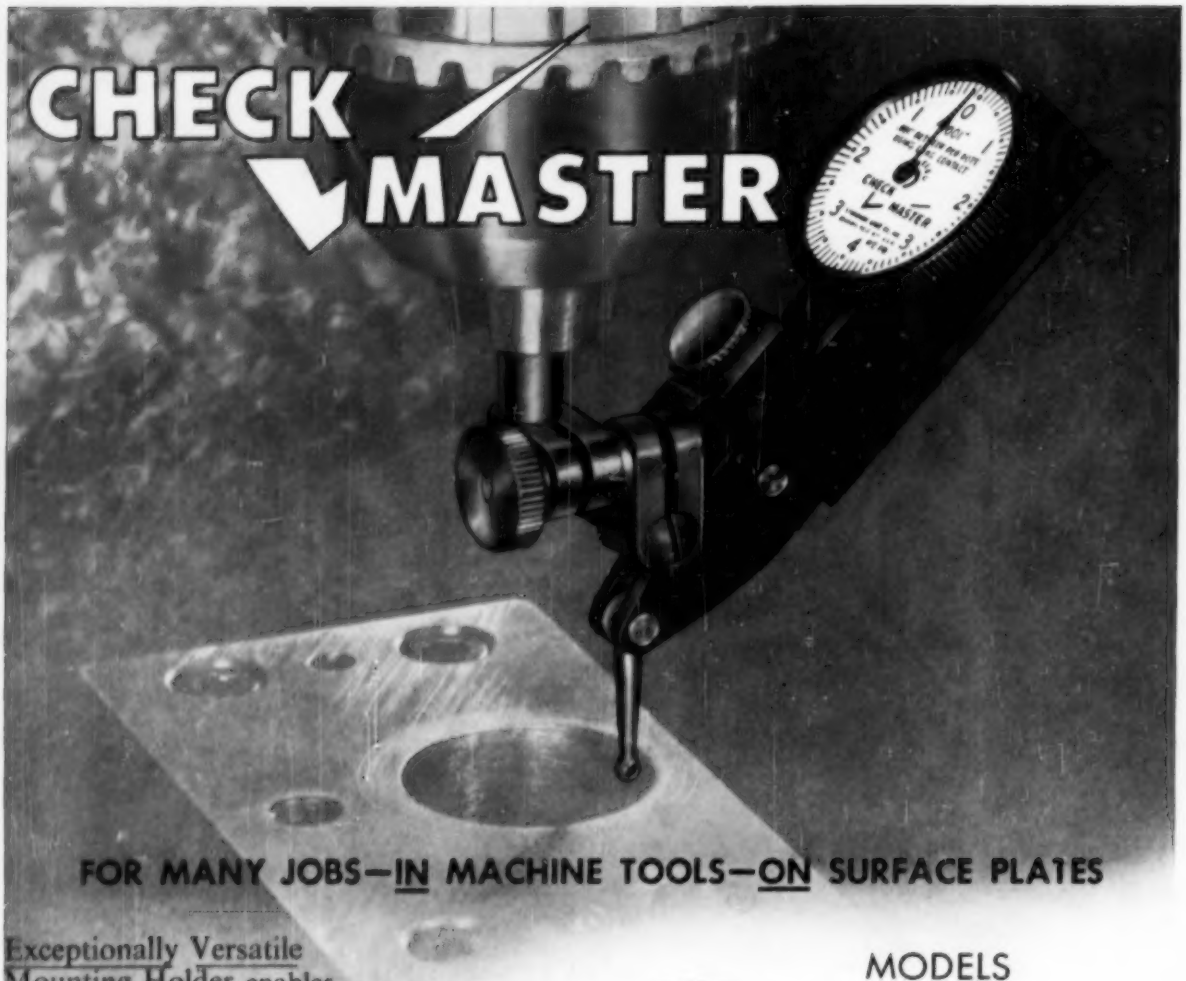
Industrial

1956—TENTH ANNIVERSARY YEAR—1956

Journal of the

AMERICAN SOCIETY FOR QUALITY CONTROL



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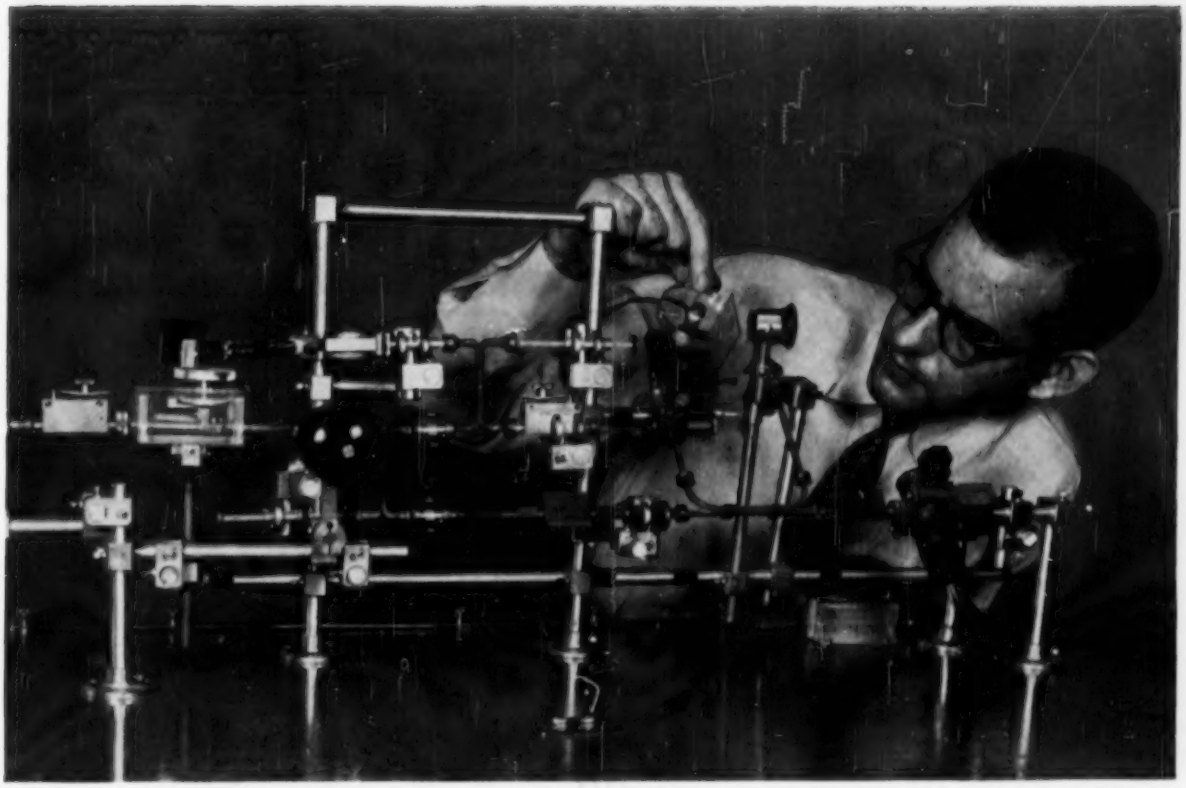


Physicist G. K. Farney checks the frequency of Bell's new klystron, which is located at far right. Tube's output is about 20 milliwatts.

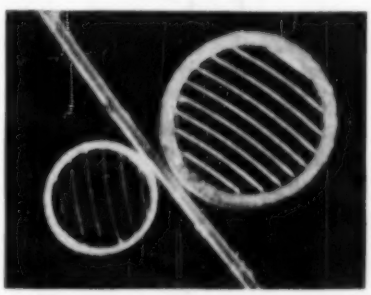
Sixty billion vibrations per second

A great new giant of communications—a waveguide system for carrying hundreds of thousands of voices at once, as well as television programs—is being investigated at Bell Telephone Laboratories.

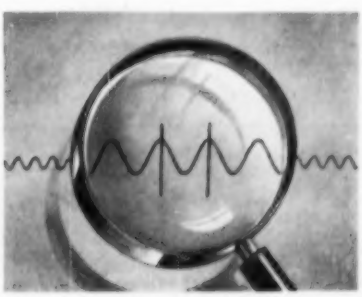
Such a revolutionary system calls for frequencies much higher than any now used in communications. These are provided by a reflex klystron tube that oscillates at 60,000 megacycles, and produces waves only 5 mm. long.

The resonant cavity that determines the frequency is smaller than a pinhead. The grid through which the energizing electron beam is projected is only seven times as wide as a human hair, and the grid "wires" are of tungsten ribbon 3/10,000 inch in width.

G. K. Farney, University of Kentucky Ph. D. in nuclear physics, is one of the men who successfully executed the development of the klystron. Dr. Farney is a member of a team of Bell scientists whose exciting goal is to harness the immense bandwidth that is available with millimeter waves . . . and to make certain that your telephone system remains the best in the world.



Grids in new tube, enlarged 30 times, with human hair for comparison. Electronic beam passes through smaller, then larger, grid.



Wavelengths produced by the klystron tube are only .2 inch long—1/15 that of the transcontinental radio relay system.

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Quality Control

Vol. XII, No. 11 May, 1956

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Industrial Quality Control is published monthly by the American Society for Quality Control, Inc. Entered as second-class matter on Sept. 18, 1950, at the post office at Milwaukee, Wis.

Executive Secretary's office and Publications office: Room 6197 Plankinton Bldg., 161 W. Wisconsin Ave., Milwaukee 3, Wis. New York Address: Room 965, 463 West Street, New York 14, New York. Advertising Representative: Weston and Weston, 6 East 39th Street, New York 17, N. Y.

IQC is sent to all members of the Society as one of the privileges of membership; yearly subscription is $5.00 of the membership dues. Subscriptions from non-members are not accepted. Subscriptions for company, public and university libraries are: 1 yr.—$9.00; 2 yrs.—$17.00; 3 yrs.—$25.00; 5 yrs.—$40.00.

Back issues of Vols. I-X are available at $6.00 per volume including index. Back issues of Vol. XI are $9.00. Individual copies are $1.00 each. Orders for library subscriptions and back issues should be accompanied by remittance in United States funds made payable to the American Society for Quality Control, Inc.

Notification of address change should be sent both to the secretary of your section and to the executive secretary's office. Allow approximately seven weeks for the change to become effective.

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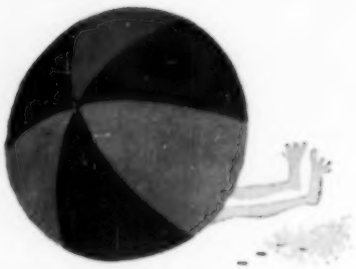
For Cuts

For Scratches



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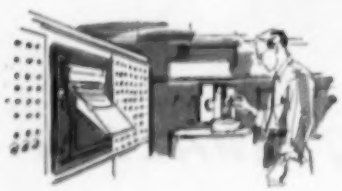
Quality Control...

You can see it Best at Alcoa in terms of a single Aluminum Forging

As far back as the melting pot at Alcoa's Massena, New York, plant, quality control was at work on this forging. Quantometers analyzed the melt in minutes to make sure the ingot, as poured, would be on the nose.



When the ingot cooled, a sample slice was taken from it, polished and etched. A powerful microscope laid bare its grain structure.

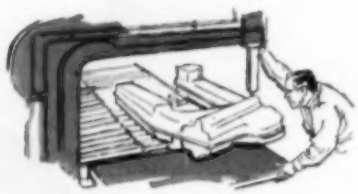
Then the ingot was rolled into a bloom—worked into finished forging stock. Ultrasonic inspection at this point combed the finished stock for hidden flaws with high-frequency sound.

On to the blocking dies at Alcoa's Cleveland forge shop. After the first 50,000-ton squeeze, the rough forging was cleaned and etched. Trained eyes scanned its surface for minor flaws and breaks. Ultrasonic instruments probed its innards for cold shuts and tiny defects.

Next the finishing dies. Now the finished forging underwent another ultrasonic inspection, etching and surface scrutiny. A test section was cut from it and tested for tensile, yield, elongation and creep. Destructive testing it's called.

Other sections, from areas of greatest strain, were polished and etched. Forging experts checked these under microscope to make sure the tough, fibrous grain structure was properly aligned for ultimate strength.

Now for heat treatment. Separately forged test bars from the same parent metal were heat-treated along with the finished forging. These samples and the finished forging, too, were Brinell tested for specific hardness.



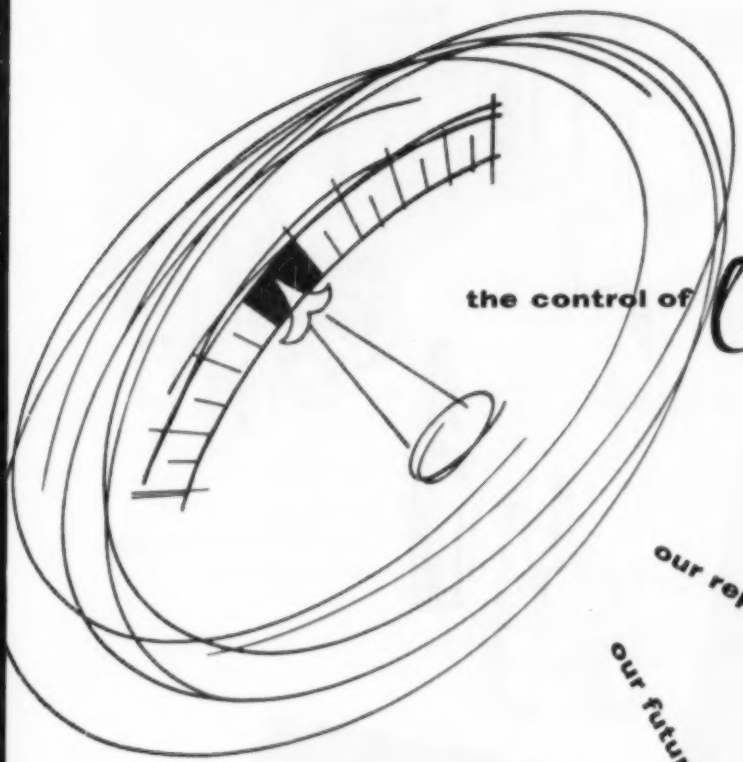
The finished forging moved on to Zyglo inspection where fluorescent dye revealed any minute surface flaws under black light.

All these tools of quality control are employed in every Alcoa forge shop on a rigid, statistical basis.

To the customer, these inspections mean fewer rejects, less wasted machine time, lower costs, avoidance of salvage operations.

To the user, these inspections mean safety and a product he can trust.

To Alcoa, these inspections are a practical definition of quality control.



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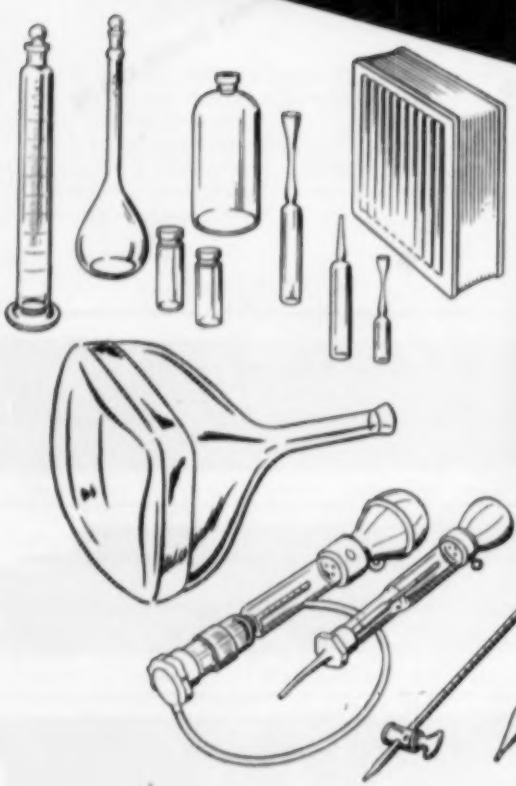

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☆ ☆ ☆ So tomorrow when you pick up your Gillette Razor, pause and think that it's not only a means of getting a clean, quick, comfortable shave—it's a little magic wand that has changed the face of the world and helped men see each other more easily and believe each other more readily.

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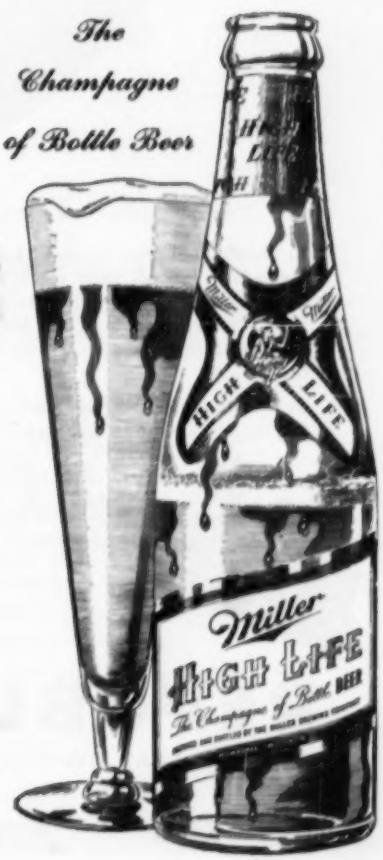

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Integrating Operations Research Into a Business

HARLAN D. MILLS

General Electric Co.,

New York, N. Y.

Introduction

There seems little question that scientific attitudes and methods can contribute significantly to the management of business operations. The real question is not whether, but how, this is to be done. More and more it is being discovered that when effective coordinate and reference bases are used in business phenomena, there exist patterns and relationships in the operations which have sufficient stability to afford real managerial leverages in planning and organizing these operations.

On the other hand the use of the attitudes and methods of scientific research seems to show very good promise of a systematic ability to develop these patterns and relationships and thereby make these leverages available to management. Bringing to management insights and skills on a systematic basis, which in the past only a very few gifted individuals could command by the sheer weight of their unaided intuition, provides the means for making management, itself, more manageable.

However, the scientist, when placed in the vast panorama of business operations, is faced with a veritable plethora of possible subjects of research. Here the problem is in addressing research to the right kind of problems and addressing the right kind of research to these problems. In addition to the variety of possible subjects, there is a perishability in the usefulness of results and an irremovability of complexities involved in business operations which are foreign to most scientific areas. For these reasons a large amount of discrimination is needed in order to channel the research into areas which can make the greatest contribution to the operations in the business. Discrimination is also needed to know where and how intuitive processes should take over for rational processes, what kind of research in accuracy, scope, and objectives will do the best job. Thus the research needs to be focused. But more than this, it needs to be usable by the managers of the business.

As in any endeavor joined by varying disciplines, there is a problem of two-way communication. As a rule, good managers haven't the life time to become good scientists and vice versa. There must be a two-way delegation of expertness and the mutual respect and confidence which accompanies this. In addition, communication between these areas of expertness has to be clear and sharp. Thus the question of how—how scientific attitudes and methods can best contribute to the operation of a business—is difficult and important. The stakes are high and the rewards for answering the question well are great.

The General Electric Approach

In General Electric our present conviction is that the how question must be answered by a complete integration of scientific attitudes and methods into the management team of the business. This concept of complete integration is, indeed, symbolized by the name Operations Research and Synthesis. This is to give an account of what is meant by this complete integration and, perhaps of more significance, to give an account of the thinking which has led to this concept.

The Operations Research and Synthesis Consulting Service in General Electric owes its existence to the charge from the management of the company to explore the possibility of applying operations research in a business. This stems from a desire to incorporate the philosophy and practice of operations research both in the long-range planning and day-to-day work of the company, if applicable and desirable.

While this charge did not endow the individuals of the service with any special knowledge, it has and is affording the opportunity to study operations research itself from the point of view of its ultimate contribution to a business. Our present convictions in General Electric are not offered as a general answer for the problem of research in business operations. They reflect, first of all, our obligations to our company, its special characteristics, its organization philosophy and its philosophy on professional management. They are also limited by our own limits in imagination, experience, and vision.

It is my experience, even though I come from the field of mathematics which has some reputation for logic, that man is not basically a logical animal. He does what he must to live day-by-day and stumbles now and then onto mental trinkets which he presumptuously calls rational patterns. I would not have you believe the sequence and structure of the ideas which follow are an historical account of our mental activities.

It is surprising sometimes how difficult it is to develop a simple idea. Yet on the other hand the human mind shows marvelous capabilities. I have seen in my associates and managers of the company that crystallized ideas, in retrospect, in their uncrystallized and uncommunicable form have, in fact, guided many decisions and stands which they have taken. Our service must thank in no little measure the gifted and visionary intuition of many individuals supported by little more than a prophetic courage.

Research and Managing

A point of entry into the how question might be an attempt to find a common ground between the disciplines of managing and science. A meeting place can be found in a predecision speculation on the part of a manager. Such a predecision speculation might be considered as consisting of two main parts separated by a logical operation. On the one hand we have inputs to the logical operation which consist of three elements—objectives, assumptions, and strategies. On the other hand, there is an output from the logical operation, say expectations.

More specifically, we mean by:

Objectives—statements about preferences in future events, a

listing, in some fashion, as to what future events are preferred to any particular possibility;

Assumptions—the appraisal of the situation itself, the facts, the estimates, and the outright guesses which are required to manage in the situation;

Strategies—various hypothetical courses of action available in the situation which can be selected by the manager;

Expectations—hypothetical outcomes arising from the various strategies which are anticipated by means of the assumptions and evaluated in terms of the objectives.

The contention is that in handling this set of elements, in constructing and utilizing them, the manager uses scientific method. The limiting condition, aside from personal training and aptitude, is principally in the lack of two resources—time and the luxury of procrastination. In research, doing nothing is doing nothing, but in business, doing nothing is doing something. That is, the difference between research and this portion of the intellectual activity of managing is a matter of degree, not kind.

At the same time, these elements display an opportunity for research in business as that of augmenting and strengthening the logical connections between the inputs of the logical operation and its output—in reducing objectives, assumptions, and strategies to more primitive levels of belief and simplicity; in refining expectations to sharper statements of consequences; and, finally, in making the logical operation more precise and communicable.

Further considerations of this little logical model and comparison with the real life of a manager introduce additional complexities into the matter. Objectives, in a particular predecision speculation, will generally have been derived from other more strategic objectives of the business. Assumptions may have to be based on expected actions of other managers in the organization, as well as on physical considerations. Likewise, strategies will usually be interrelated with possible strategies of other managers in the business. The expectations are in the final analysis aggregated into a total performance of the business as a whole.

In addition, it is one thing to arrive at a decision and another thing to implement it through a large organization of people. Motivating and integrating individual actions in a common cause is part of the intrinsic job of a manager. To accomplish this requires clear, sharp communications not only of facts but of attitudes, concepts, and criteria for spontaneous action and initiative. Managers use this logical model for communicating decisions as well as making them—it furnishes a framework and a vehicle for transmitting information into the organization.

As you know, General Electric is organized under a decentralization philosophy. This philosophy calls for components which have a high degree of uniqueness and completeness with respect to the markets they serve. Thus these components are, to a high degree, individual businesses. These businesses are, each, incomparably simpler and easier to visualize than the entire General Electric Company—it is intended that they be so in order that the general manager of one of these businesses can get his intellectual arms around it.

The organization philosophy further calls for sharp lines of responsibility and accountability. The basic responsibilities and accountabilities of the company converge in these relatively autonomous businesses in long-term profit and loss responsibilities. These "building block" businesses of General Electric furnish two critical conditions:

- To a high degree they are, economically, "whole operations."
- To a high degree they are, managerially, "whole organizations."

These considerations, with those of the logical model of the managing process, lead to a concept which is crucial to the entire General Electric approach and which is a major basis for defining the integration of research into business operations. It is the concept of the **hypothesis of a business.**

The hypothesis of a business is an extension of the predecision speculation model, already mentioned, in two dimensions. First, notice that the logical model, as discussed, is concerned with a single manager in a static situation. The extensions of this logical model which lead to the concept of the hypothesis of the business are in the dimensions:

- Across the managers of the business;
- Across time.

The first extension, across the managers of the business, and the implicit structure of responsibilities, authorities, and expertness they induce, leads to a structure in each of the elements—objectives, assumptions, strategies, and expectations. Thus the objectives in a business are the complex of objectives under which the individual managers of a business are operating. They are represented by the objectives of the business, as an entity, from which presumably all the other managerial objectives are derived. Likewise, assumptions, strategies, and expectations have structures over the managerial positions, all stemming from the assumptions, strategies, and expectations of the business as a whole. These structures are interrelated—a strategy at one position may be reflected in an objective in another, etc. In this sense then we can think of a logical model in which the elements are objectives, assumptions, strategies, and expectations considered as interrelated structures over the managerial positions of the business.

The second dimension, over time, makes the model a dynamic one. Objectives, assumptions, strategies, and expectations are usually in a state of flux, depending upon the particular situation of the whole business. As a dynamic concept, there is going on, in time, a continual re-evaluation, re-orientation, and respecification of the elements of the model. In place of static decisions the realities are that of a dynamic participation in the flow of events of the business.

The hypothesis of a business, whether implicitly or explicitly stated, serves as a communication medium throughout the business. It is the means by which decisions are implemented through large groups of people; possibly more to the point, it is the means by which management is managed in a business.

Whereas the static predecision speculation on the part of a single manager displayed an opportunity for research in business as augmenting and strengthening this logical model, the hypothesis of a business affords also an opportunity for research in business in a much larger and much more important sense. In fact, it is the present conviction in General Electric that the strengthening and sharpening of the hypothesis of the business must be the major responsibility and goal of Operations Research and Synthesis.

Operations Research and the Discipline of Managing

One of the striking realizations of a relative outsider in viewing the

inner workings of a large modern business is that a new power exists in the American scene—it is the power of the principles of the organization of human efforts. Wiener has expressed it very nicely in the phrase, "The human use of human beings."

One of the basic principles of organization in General Electric is to identify the work which needs to be done by a component and then structure the organization around this work in such a way that:

- Any position can be filled by a single person whose stature corresponds to the level of that position;
- Every position is structured into clean, unambiguous lines of responsibility, authority, and accountability.

This corresponds to the philosophy in some universities of observing where students walk and then building the sidewalk accordingly. A criterion of good organization can be inferred here—the closer the informal organization coincides to the formal organization, the better it is.

The difficulty of communication between managers and scientists—as two extremes of an in fact continuum—makes sound organizational thinking all the more imperative. One might imagine a marketing component structured in a most haphazard way formally, and yet informally getting its "lines" through to the rest of the organization on a good enough basis to get by. It is much harder to imagine this feat being accomplished by a team of scientists, especially when the business is not in any apparent trouble.

These principles and background lead to a conviction that the power of Operations Research and Synthesis in General Electric must stem first from the power of the principles of organized efforts. This is not to deny the necessity for the go-power which comes from knowledge and skill in business, logical, and scientific processes. It is a necessary prerequisite.

The hypothesis of the business has already been identified as an object around which the work of Operations Research and Synthesis can be defined. This is used then to structure the responsibilties, authorities, and accountabilities of Operations Research and Synthesis into a General Electric business. A primary objective in this organization concept is to enable the rest of the business to depend on the component to discharge well-defined responsibilities, as opposed, say, to the philosophy "Operations Research and Synthesis is a good thing—we're hoping for great things out of it."

In a word, to be usable Operations Research and Synthesis must be manageable itself. This means it must be manageable as a service of a business—that it contributes in a responsible and predictable way. This further implies that it must be manageable internally—that we must learn how to manage research on business operations.

There is no forgetting that research work is highly creative. However, there are several reasons for hope that it can be done. First of all any real managing work is highly creative and yet manageable itself. There is also the saying on the links that "you drive for show and putt for dough"—this seems to apply with equal validity to business operations. This fact of importance of the multiplicity of little things rather than the scarce, spectacular ones is probably one of the real secrets behind the power of organized efforts and also applies to organized research on business operations.

Implicit in the integration of such a service into a business is the necessity of a fundamental philosophy of science. The entire management team must be aware of what logical and scientific objectives and values are. Businesses are run and always will run on the basis of the beliefs of its managers and not on the basis of "truth"—whatever that means. The role of logic and science is to enable the managers of the business to go forward with a little more confidence in their own rationality—it cannot do more. It is important that no more than this is expected.

With a fundamental scientific philosophy in the business, a host of perplexing questions vanish from the scene. The question of recommendation by the Operations Research and Synthesis service and its relation to objectivity simply does not exist. Operations Research and Synthesis is incapable of asking the question "What should a manager do?" It can only ask "What information and concepts are needed?" An Operations Research and Synthesis manager is as vitally involved in the business and as responsible for personal risk taking as any other manager. The objectivity comes from the disciplines used in the service rather than an arbitrary mental curtain.

These, then, are the elements of General Electric's approach for integrating Operations Research and Synthesis into a business.

- For **intellectual integration:**
  Specific work arising out of the total responsibilities of the management of the business—the study of the hypothesis of the business.
- For **organizational integration:**
  A structure of organized efforts to accomplish this work by means of a manageable service of the business.
- For **emotional integration:**
  A fundamental philosophy of science and its relation to managing.

These elements lead to the following characterization of Operations Research and Synthesis:

- A permanent service reporting to the general manager of the business with two kinds of responsibilities:
  - Functional responsibilities—the responsibilities for describing and refining the hypothesis of the business and exploring, as directed by the general manager, possible alternative hypotheses.
  - Relationship responsibilities—the responsibilities for cooperation with operating managers, as directed by the general manager, in describing and refining hypotheses of operating problems.

  For both kinds of responsibilities the service is accountable to the general manager, and they are delegatable only by him. The service may suggest specific responsibilities but the authority to create them is reserved for the general manager.
- Out of these responsibilities arise the authority and opportunity for employing the attitudes and methods of operations research and, as importantly, for encouraging the increased use of these attitudes and methods by the operating managers themselves.
- The Operations Research and Synthesis service is not a collector or processor of operating data for operating use. It is a research service, not a control.

There are calculated risks in this approach—the General Electric

manager is to be self-involved, as never before, with day-to-day research on business operations. It is inherent in the above remarks that Operations Research and Synthesis does not seek out the quantitative problems of the business—it is intended for the important problems of the business. As such, manager participation in the research is not simply desirable—it is absolutely necessary. It is hardly necessary to remark that the willingness of General Electric to take this risk is a profession of confidence in the intellectual and emotional stature of its managers.

Research in Business Operations

As noted, the effectiveness of Operations Research and Synthesis, if organized and integrated into a business, hinges on its go-power of knowledge and skill in business, logical, and scientific processes. A premise for this entire endeavor is that this go-power exists.

Whereas technologies have literally been built out of physical sciences and draw directly out of them, there is a fundamental difference when one attempts to apply logic and science to business operations. First, business operations do not and have not grown out of science, except as technologies are used in them. This is possible because of an important difference between managing and a technology.

In a technology the primary concern is existential problems— problems of kind; in managing the existential aspect of problems is minor and the problems are primarily those of degree. That is, a technology is concerned mainly with doing something at all, whereas managing is concerned with doing something better that which is already being done or can be done.

For example, the mathematics used in designing a television set is chiefly concerned with its literally being a television set—working at all. The mathematics used in managing the manufacture of television sets is not at all necessary to get the sets produced—it is used to get the sets produced efficiently.

This difference between the existential technologies and nonexistential managing reflects itself in the kind of intuition which can be brought in. In a technology intuition is of a very limited and formal nature, say, in the form of the rules of arithmetic, Newton's laws of physics, or the basic electromagnetic laws. On this very simple base a very complex, logical structure is erected such as electrical engineering, and at each step in its progress the structure is extremely well-defined and documented. In managing, the situation is just the opposite. A tremendous body of informal intuition is available with, compared to technologies, very little formal structure.

This means that communication in managing is much more difficult than in a technology for the formal structure of a discipline is the sole means of communication in it. Here is the reason that "laboratory" analyses cannot be effective in business operations—the intuition of situations cannot be put into an amenable structure. This also raises the question of the validity of ordinary scientific procedures and the role of logical processes in research on business operations.

In the case of technologies logical processes are used primarily to bring rigor to problems. In managing the distinct possibility arises that logical processes should be used, to a great extent, to bring imagination to problems. That is, logical concepts which may make one think "why didn't I think of this before?" only one wouldn't have!

As an example of this, in a particular situation of uncertainty in future sales, a logical analysis of the situation suggests a concept of marginal value in producing an item, as the chance of selling the item times its price plus the chance of not selling the item times its inventory value if held over. This is an extremely simple and plausible idea, yet no one thought of it before the logical analysis was made. No appeal is made to rigor, now. This concept is required to stand on its own merits as a first principle.

Similarly, principles of inductive inference need reviewing—chance events are rare in business operations, causes and effects remote. The rationale for probability, or mathematical statistics, analyses is on a different base than that of physical operations. Where a 95 percent confidence may be typical in physical operations, a 65 percent confidence may be a more realistic level in business and mean something quite different—say a shift from an "unassigned cause" in a physical operation to an "indeterminate action" in a business operation.

These are undoubtedly some of the superficial realities of bringing logical and scientific concepts into business operations. Further insights will show up as research is truly integrated into business operations. The nature of the research itself is a large factor in this integration. If the researcher is primarily concerned with getting numbers from managers to take back to the calculating machine, he will never get a glimpse of the problems of the business.

A business organization is much more of a logical computer than a first glance indicates. Paradoxically, the situation which looks like a natural for scientific research is often where the managers need it least—for it is just these properties which allow a systematic accumulation of experience and know-how to be built right into the organization.

Conclusion

The potential of scientific philosophy and practice as a participant in the operation of a business is probably little appreciated, even by our optimists. A limitation in the realization of this potential is the sophomore in all of us, both in regard to vision and complacency. It is probably safe to say that the misuse of ideas is fully as responsible for limiting human progress as the lack of them. In view of this, three notions are submitted for consideration.

The first notion is that a business ultimately exists solely for the purpose of individual human expression —the voluntary cooperation and organization of many individual resources and talents for a greater contribution as a whole and more satisfactory expression as individuals. While the operation of a business requires both ethical and intellectual principles, the appropriateness of the intellectual principles must stem directly from the ethical ones.

Secondly, there is an important distinction between the study of organized human efforts and the physical sciences—it is in the fact, in the first case, that the complexity of the objects of concern is not independent of the methods of study. Whereas, say, the structure of an atom will "hold still" while more powerful methods for its study are developed, the very progress of science and technology demands an increase of specialization and complexity in the organization of human effort. It is easy to fall into the trap of appraising our abilities to study yesterday's problems with today's methods. Carried out to extreme, this mental lapse can produce an illusion that the intellectual activity of a business can ultimately be specified by formal science alone.

We cannot afford to see only the wondrous progress of science and technology, with the more powerful methods of study it produces, while overlooking the advancing specialization and complexity in the organization of human effort this very progress demands.

Finally, the sober and continuous recognition of the inherent abilities of the human mind and intuition is submitted as a necessary means for the realization of the potential of science in business. This marvelous instrument is available which can compute, not only in black and white, but in all shades of gray. The human being must not be factored into business operations by science as an afterthought or a necessary evil; he is the most powerful logical instrument available and other scientific devices must be integrated around him.

No amount of words or concepts will themselves produce research—this is a property of people, their imagination, their industry. The contribution of operations research work must finally hinge on the quality of the research itself. The approach presumes and requires a quality research effort. It is intended simply to set a framework in business and science in order to make effective contribution of research possible.

No panacea has been discovered. The only resolution proposed is embedded in an entire notion of research on business operations represented by its intellectual, organizational, and emotional integration. It is not proposed as an easy answer, or even an answer at all. It is a way of thinking—not for scientists or managers separately, but for scientists and managers together. This way of thinking represents an effort to structure operations research into the discipline of managing, as understood in General Electric, so that it becomes an integral part of the total work of managing the operation of a business.

Management of the Quality Control Function

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There is little question that the growth of quality control has been one of the major forward steps that industrial practice has taken in our economy during the past decade or more. This is true both for commercial production and for defense activities. There is much, therefore, that those interested in quality control can see as genuine and heartening progress.

One of the keys to this progress is the fact that industrial top management in the United States is taking quality control really seriously as an overall management method. The test that many progressive company presidents apply to their quality control program today is not a test of its adequacy as a statistical analysis effort alone, nor its adequacy as an incoming sampling activity alone, nor indeed its adequacy as a shop process control effort alone. The acid and final test that top management uses is a *business* test:—a measurement of the positive contribution that quality control makes to the effectiveness, service, and profitability of the total enterprise.

The elements of product quality are closely entwined with the very roots of a company—with its marketing activities, with its inventory control, with its product planning, even with its industrial relations. A mature, genuinely satisfactory modern quality control program is one which, on an overall, factory-wide basis, regularly comes to grips day by day with all of these product quality elements. The program may be modestly organized in its early days as a matter of reject analysis, incoming sampling, or process analysis. Its ultimate goal, however, must be overall control of plant quality wherever this quality is to be found.

Such a goal for quality control as a genuinely top-level management program in a company—comparable directly with other top-level management programs such as production control, budget control, personnel administration—is in effect the goal of managing the modern quality control function.

What must we quality control men do to achieve this goal? How should we organize? How should we train people? How should we establish plans and programs? How should we develop equipment fully to achieve our product quality objectives?

Coming to grips with questions such as these is the purpose of this article and the one that follows it.

In reviewing management of the quality control function, there are three facts about quality control in modern American industry that I believe we must initially face squarely.

The first fact is that customer quality requirements have been increasing very substantially in recent years in the United States—a trend likely to be greatly expanded by the intense quality competition that is inevitable in the next several years.

Certainly we see this trend in our business. The relay that could command the lion's share of the 1948 market is no longer acceptable for 1956 operating needs. Quality levels for motors and for generators are being appreciably tightened year after year. Consumers are progressively more precise in their examination of the finish of appliances, or in their judgment of the tone of a radio or television set. Even for those most critical products on which human safety already depends—jet engines, airborne electronics, ordnance — military quality requirements are being made progressively more sensitive.

I am sure that evidence of these tightened quality trends is clearly recognized in other businesses as well.

The second fact is that, as a result of this increased customer demand for precision products, present quality practices and techniques are being rapidly outmoded.

The machined part that could once be checked with a pocket scale must now be carefully measured with a pair of precision micrometers or an air gage. Material that could once be visually accepted if it were "reddish brown and shiny" must now be carefully analyzed both chemically

and physically to assure that it is beryllium copper instead of phosphor bronze.

Electrical testing requirements have been calling for more and more complex testing equipment. Intangibles like dust in the air and humidity have become both extremely tangible quality problems and the object of elaborate safeguards. Many methods for measuring quality, quite satisfactory even as short a time ago as the Korean War, no longer meet present demands. And, of paramount importance, improvements in inspection and test productivity have been far from what they should be.

Fact number three is that the costs of supporting even the present levels of quality have become excessive. For many companies, these quality costs may well represent seven, eight, ten percent and more of their cost of sales. In many cases, this means 70, 80, 100 percent and even more related to direct labor dollars. Quality costs have today become a major multi-million dollar expenditure item comparable in degree with direct labor dollars, materials dollars, selling dollars.

Taken together, these three facts spell out the double-barreled objective for a company quality control program under 1956 competitive conditions: first, a considerable improvement must be effected in the quality of those products and quality practices which require such improvement; second, a substantial reduction must at the same time be made in the costs for maintaining and improving product quality.

What does it take for a business to achieve this objective? What methods must it use? Which individuals and functions must be held responsible for results? What is the quality accountability of the design engineer, of the manufacturing manager, of the foreman? What is the function of the inspector and the tester?

Will the company have to spend money to make money in meeting this objective? If so, how much? How can the company measure effectiveness in reaching its goal? What is par for the course in terms of effectiveness standards?

These are not easy questions to answer. The answers are not easy to put into operation. But the answers do exist, of course, and they are beginning to work effectively today in several companies including—we like to think—the General Electric Company. The answers have simmered out of the many

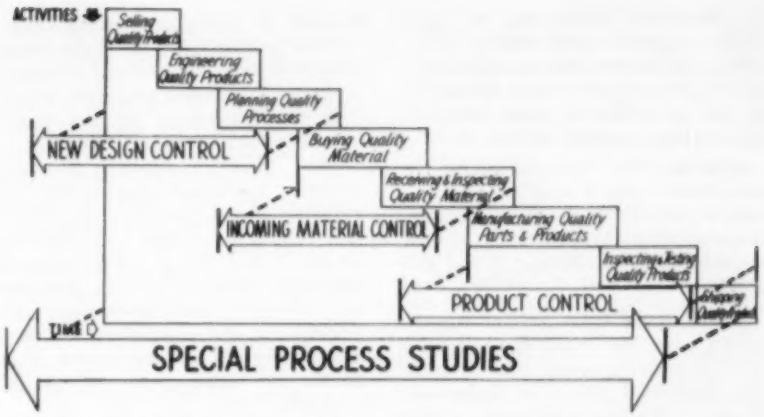

Figure 1—Quality Control Activities During the Manufacturing Cycle*

years of quality experience both in our country and elsewhere in the Western world. They are based upon two fundamental principles of quality control building which I would like to review.

Principle One: Quality is everybody's job.

The quality of a product—a relay, for example, has been affected at many stages of the manufacturing cycle. It has been influenced by the *marketing function*, which evaluated the level of relay quality that customers wanted and for which they were willing to pay. It has been influenced, to a major degree, by *engineering*, which reduced this marketing evaluation to exact drawing specifications.

It was influenced by *purchasing*, in choosing, contracting with, and retaining vendors for parts and materials. It was influenced by *manufacturing engineering*, in its selection of the jigs, tools, and processes for relay production.

Manufacturing supervision and *shop operators* had a major quality influence during parts-making, subassembly, and final assembly. The important effect of *mechanical inspection* and *functional test* in checking conformance to specifications almost goes without saying. *Shipping* had its influence in the calibre of the packaging and transportation.

This clear-cut quality activity sequence during the manufacturing cycle demonstrates that the modern quality control management job cannot be accomplished by concentrating upon inspection alone, or design alone, or reject trouble shooting alone, or operator education alone, or statistical analysis alone—important as each of these individual elements is.

The quality control job requires a complete and positive program involving *all* the elements which influence product quality. This program starts with the design of the product and ends only when the product has been placed in the hands of a customer who remains satisfied with it. The work supporting this program falls into four natural classifications, which are: (See Fig. 1)

1. The control of new or modified products prior to the start of production, or NEW DESIGN CONTROL.

2. The control of incoming purchased parts and materials, or INCOMING MATERIAL CONTROL.

3. The control of materials, parts and batches from machines, processes, and assembly lines, or PRODUCT CONTROL.

4. The conducting of special analyses of factory and processing problems, or SPECIAL PROCESS STUDIES.

These elements are, in effect, the four sub-jobs of the overall quality control management job.

Collectively they cover the four major phases of the quality activity cycle. Each of them is supported by definite methods and procedures, which must become as much a part of shop practice as are production control or cost control routines.

The approach at the core of these procedures is *preventing* poor quality, rather than "winging" or correcting poor quality after manufacture. They are designed to *build up* operator responsibility and interest in product quality. They recognize that, in the final analysis, it is a pair of operator's hands which performs

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the important operations affecting product quality—and that it is of paramount importance to successful quality control that these hands be guided in a skilled, conscientious, and quality-minded fashion.

Principle Two: Because quality is everybody's job, it may become nobody's job—*To forestall this result, responsibility for quality control must be carefully delegated and defined.*

There have been many experiments over the years to make the quality control cycle that I have just described less of a Tinkers-to Evers-to Chance sequence. Often these attempts have taken the form of establishing a function whose job responsibility is stated as "all factors affecting product quality."

These experiments have had a life span of as long as six months—when the job incumbent had the advantage of a strong stomach, a rhinoceros hide, and a well-spent and sober boyhood. Others not similarly endowed did not last six months.

The simple fact of the matter is that the *marketing man* is in the best position to evaluate adequately customers' quality preferences, the *design engineer* is the only man who can effectively establish specification quality levels; the *shop supervisor* is the individual who can best concentrate upon the building of quality.

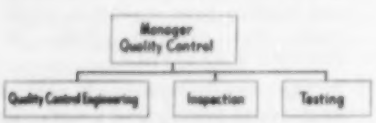

Figure 2
Functional Quality Control Structure

Successful execution of the quality control job clearly requires, as a first step, the re-emphasis by top management of the quality responsibilities and accountabilities of these and all other participants in the quality control cycle.

With a program that costs many companies millions of dollars annually, it also requires a second major step on the part of top management: that these responsibilities be buttressed and serviced by the operation of a recognized, well-organized, genuinely modern management function whose only area of specialization is product quality.

In the General Electric Company, such a modern quality control function has two basic responsibilities:

First: To provide *Quality Assurance* for the business' products.

Second: To assist in assuring *Optimum Quality Costs* for those products—indeed, it is formal recognition of this second objective which is the trademark of the truly modern quality control function.

The quality control function achieves its *first responsibility* by carrying on the *minimum inspection and testing necessary* both fully to establish that the products shipped are of the specified quality, and also to thoroughly feed back facts for preventing the production of poor quality material in the future. This is the operating phase of quality control.

Responsibility number two is achieved through quality control engineering work: first, through specialized professional quality control service to all participants in the quality control cycle: second, by means of the planning, analysis, and standards-setting effort necessary for adequate pre-production, vendor, in-process, and pre-shipment product controls; and, third, through carrying on the measurement and integration activity required for quality cost control and improvement, including the reduction of manufacturing losses and customer complaints.

Directly related also to responsibility two is the providing of genuinely modern effort in the *design and maintenance* of inspection and testing equipment. The emphasis of this activity is upon economical investment expenditures, maximum equipment utilization, and fullest practical mechanization and automation both of operations and of paperwork.

This quality control engineering work is therefore a genuinely new phase of the engineering profession. While the use of statistical methods are important to it, statistics are but one of a number of the tools in the quality control engineering kitbag.

The modern integrated quality control function thus packages into a single, high-powered rifle cartridge, the individual scattergun pellets of quality maintenance and quality service. Its quality control manager represents, in a single individual, responsibility, authority, and accountability for the business's product quality assurance, and for service which fosters optimum quality cost. His three sub-functions—quality control engineering, inspection, test—provide him the organizational tools needed to meet his objectives. (See Fig. 2.)

It is well to emphasize that the core of the modern quality control function is its feed-back cycle consisting of planning, measuring and analyzing.

Quality control engineering does the planning, while inspection and test do the measuring with rapid "feedback" to quality control engineering for analyzing—which results in new planning.

The advantage of this type of feedback is that proper planning may be accomplished through the information received from measuring and analysis. The planning can then be varied to accommodate given circumstances. Electronic regulator specialists will recognize a direct analogy between quality control's organizational feedback and the technical feed back cycle of the modern servomechanism. (See Fig. 3.)

Figure 3—Quality Control Feed-back Cycle

An old English proverb tells us that "Those who must shake their fists should first be sure that they have arms." It continues by stating that "After they have made sure they have arms—and when others know it—there is no longer so much need for shaking their fists."

As major segments of the modern quality control function, inspection and test activity has the potential for full development in the direction that conscientious inspectors and testers have always sought: an activity with a positive role in assisting other members of the manufacturing, engineering, and marketing team toward quality improvement and quality cost control—not an activity whose essentially negative "fist-shaking" role in sorting bad parts from good places it continually on the defensive.

In the integrated quality control function, the several tools of statistical analysis that have proved practical and useful can be brought to their fullest effectiveness. With the quality control engineering tool builders and the inspection and test tool users as full partners on the same team, statistical techniques can be put to work in a down-to-earth fashion that welds them into regular day-by-day controls, rather than uses them—as too often in the past—

merely as gimmicks to be employed in special situations on a pinch-hitting basis.

With equipment in the inspection, testing, and quality-level indicating fields a direct and major responsibility of this quality control component itself, rather than of some organization elsewhere, more specific attention can be given to the equipment specialists who wish to concentrate their skills on the great needs and opportunities, and the unique complexities, of the quality control equipment field. With today's increasing industrial emphasis in the United States upon the fullest automation of manufacturing facilities, quality control equipment must more than keep pace if the quality control function is to make its necessary increases in inspection and test productivity.

The basic concept of this integrated approach—which makes the quality control whole greater than the sum of its individual parts—has been many years in the building. But as a matter of standard practice throughout American industry it is frankly new.

It has been and is being put into effective operation by a rapidly increasing proportion of companies as they face up to meeting today's major quality problems. There is increasing evidence from these companies—and certainly it is our firm belief in the General Electric Company—that this integrated "MAKE IT RIGHT THE FIRST TIME" type of quality control function is beginning genuinely to pay off in six ways:

First: *improved product quality.*

Second: *reduced manufacturing losses, complaints, and better overall Quality Costs.*

Third: *better product design.*

Fourth: *elimination of production bottlenecks.*

Fifth: *improvement of processing methods.*

Sixth: *development of better spirit of quality-mindedness in the plant.*

While delivery and other factors may sell a product the first time, it is quality that keeps the product sold and which keeps the customer coming back a second and a third time. Quality cost—perhaps eight percent or more to cost of sales—is one of the major elements of product cost that must be made right to permit the setting of the right price to the customer. Helping to assure this right quality at this right quality cost is the way in which the modern 1956-style quality control function will serve its company in the competitive struggle ahead—in which product quality, and modern quality control operated as a management method, will be one of the major factors in the survival, health, and progress of a company.

Acknowledgement

Some of the material in this article is after the book *QUALITY CONTROL—Principles, Practice and Administration* by A. V. Feigenbaum: McGraw-Hill Book Co., Inc. 1951.

Quality Control Engineering

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In recent years, the accelerated use of statistical application in quality control has, in many cases, overshadowed the principal objectives of a quality control function—which are the assurance of quality, and quality at optimum cost. All too often experience has shown that there is need for much more than pure statistics to obtain quality improvement and quality cost reduction. For example, a major requirement is a clear, forceful method for presenting the magnitude of the quality activity to management so that adequate consideration can be obtained for quality administration.

In General Electric, we have developed a method that precisely defines the scope and importance of quality in terms of dollars and its effect upon the competitive position and profits capability of an organization. We have called this method "quality cost analysis." The analysis consists of systematically listing all those quality items connected with manufacturing and assigning the actual dollars expended for quality assurance and for failure of quality.

Quality costs for a typical manufacturing organization can very well consist of the following.

• In *manufacturing:* all costs of testing, if direct labor; dollar losses such as scrap, rework and extra costs due to quality; inspection delays, which are costly; and specific power charges for testing. Indirect manufacturing expense such as laboratory acceptance charges (inspection costs); part of manufacturing supervision (that time spent on quality activity); that part of purchasing and cost which deals with quality problems; idle time due to quality; and quality training. Obsolescence can also be considered a quality cost, especially when a change is made solely to improve product quality.

• In *engineering,* we have a certain amount of dollars spent on quality for:

Engineering and drafting costs
Shop work
New patterns and tools
Maintenance
Underwriters' Laboratory

• Finally, in *marketing,* quality costs are made up of complaints.

The initial importance of such a quality cost analysis is that it clearly pictures for management the need for having a strong, effective quality control function—a function whose authority and responsibility must be of such a nature that there can be no hindrance for the necessary activities to improve quality and reduce quality costs. This type of analysis enables the estab-

lishment of bogeys and also assists quality control to measure its efforts in meeting its objective of "assuring the right quality at optimum quality costs." It is a phase of the quality control activity that can best be accomplished by a quality control sub-function whose full-time job in this area is unhampered by having to solve the everyday "putting-out-the-fire" type of problem.

In General Electric we have come to recognize this modern quality control activity as quality control engineering, which teams up with inspection and test to integrate the quality efforts of the line and functional groups within the four quality control activities of new design control, incoming-material control, product control, and special process studies.

The responsibilities of the quality control engineer can be better understood by reviewing the work elements of his job. These work elements can also be considered as the tools available to the quality control engineer for accomplishing the objectives of his subfunction.

1. *Vendor evaluations, ratings, and certifications*
   Better quality products will result if a quality control engineer can appraise the quality potential of prospective vendors by analyzing the results of inspection findings on vendor materials. By evaluating these results and comparing them with the vendor's past performance or against the performance of other vendors, he can obtain quality ratings which will aid in the purchase of better materials. A plan of adequate vendor certification, subject to periodic checks, will help in the purchase of better materials at lower cost. Some of the certification data can be profitably used in later operations.
2. *Pre-production quality planning service*
   In this area, quality control engineering can assist design engineering and manufacturing in obtaining answers useful in pre-production quality planning by classifying information from vendor evaluation, product controls, process capability studies, and special process study analysis on new and modified products.
3. *In-process quality planning service*
   By feeding back information on complaint analyses, tolerance analyses, and process capability studies to design engineering and manufacturing engineering, and, by conducting special quality process studies, the quality control engineers will aid in the modification of parts and processes for quality results.
4. *Inspection and test quality planning*
   By identifying critical dimensions and characteristics on parts and products for inspection and test, and by specifying quality levels and methods of sampling for acceptance, the quality control engineer will aid in controlling product quality.
5. *Quality records development and analysis*
   This consists of the development of forms and procedures for recording quality data, for analyzing it, and for feeding information back for corrective action.
6. *Quality costs analysis and reduction*
   Quantitative measures of the costs of quality aid in the establishment of plans for manufacturing loss reductions and complaint reductions, and serve as a basis for establishing and measuring performances.
7. *Quality control training*
   Training people in the use and understanding of quality control techniques and developing quality-mindedness throughout the organization insure quicker and better use of control procedures.
8. *Establishment of controls*
   This consists of establishing controls for the prevention of quality defects at incoming, in-process, and final inspections. The type of control will vary, depending upon the nature of the product and the quantity produced.
9. *Quality standards*
   By working with engineering, where practical, in the establishment of quality standards on such items as appearance, surface uniformity, color, etc., the quality control engineer will aid considerably in controlling product quality and reducing quality costs.
10. *Process capability studies*
    By performing and promoting the application of such studies, which will show the quality limits within which a machine or process can be expected to operate, the quality control engineer will assist in the routing of parts to machines or processes capable of maintaining specification limits.
11. *Quality audits and rating*
    Final or in-process quality audits will supply information which can be fed back to improve or correct product controls. Establishing ratings on the quality audits can serve as a basis for establishing and measuring performances.
12. *Statistical methods*
    Frequency distribution studies, control charts, attribute and variable sampling plans, significance tests, correlation studies, and designed experiments can be used to present and analyze data.
13. *Special process studies*
    The quality control engineer should conduct special analysis of unusual manufacturing and processing quality problems whenever required for quality trouble-shooting.
14. *Customer quality certification*
    It should be remembered that most of us are not only customers of vendors but that we are also vendors to customers; therefore, we should develop quality certification plans for products we ship to customers, when desirable.
15. *Quality instructions and manuals*
    The writing and publishing of quality instructions and manuals are the quality control engineer's job when required by customer contracts.
16. *Design and fabrication of testing equipment and inspection tools, fixtures and gauges*
    Design and obtain equipment to perform testing and inspection operations in accordance with product design requirements and with requirements of engineering specifications: develop new inspection and testing methods and techniques.

Now that we have defined the quality control engineering job, stated the need for it, and listed the work elements of the job, it appears advisable to restate the four quality control activities, show how the quality control engineer can contribute to each activity, and list the work elements related to each activity.

New Design Control

The chief function of a new design control is to provide information which may be useful for obtaining the best design possible. Much valuable information

is available in both quality control engineering and manufacturing engineering as a result of accumulated experience on past projects. Quality control engineering can be of decided value in analyzing and classifying this information and making it available to the design engineer.

Let's look at the quality control engineer's contribution and his work elements, in the New Design Control activity, by listing them in accordance with the various stages encountered in design engineering.

Stage 1—New or improved design request and preliminary selection for this request.

Quality control engineers can assist in setting specifications by presenting data from field and manufacturing complaints which have been obtained from previous similar designs or from vendor data evaluations and quality audit studies. Thereby, certain troublesome items specified in the new design may be reduced. He can also advise on the standardization of materials where feasible, thereby eliminating the manufacture of various "specials" which may be troublesome. He can present a statistical analysis of data gained from studies of tolerances in the factory and from process capability studies on assemblies, processes, and machines, which will help the design engineer "loosen up" on special tolerances and still maintain the over-all desired tolerance. Tolerance analysis through the root-mean-square method will also assist in obtaining improved and less costly designs.

Stage 2—Preliminary design.

In this stage, the design engineer has the opportunity to try new materials and processes and can provide such information to the control engineer. Quality control engineering, through the relationships with vendors and the laboratory, can furnish data that can be invaluable to the new design. It can provide such information also by analyzing past statistical data from designed experiments, correlation studies, and control charts. Shop run tolerances and practices can also assist here.

Stage 3—Testing handmade samples.

After preliminary sketches or drawings have been completed, a handmade sample is prepared. The new design is then put through studies and tests as required. From these, the quality control engineer should make a statistical analysis of results, since this is the point where decisions are made which can aid in eliminating defective production. He should also re-evaluate tolerances for economic production and determine and evaluate the main variables.

Stage 4—Analysis of tests and preliminary planning.

When the design is ready to be turned over to the manufacturing group, quality control engineering can give a thorough analysis of the new design and exchange information with manufacturing engineering concerning special jigs, fixtures, tools, inspection, and testing devices as required to do a quality job at reasonable costs. At this point, test and inspection instructions should be considered and arrangements should be made for special studies as required on possible sources of trouble and their analysis so that the proper type of product control can be established.

Stage 5—Final design.

In this state, quality control engineering should carefully review the final design in terms of tolerances and manufacturing practices. By using these analyses, the design carries the assurance that if the parts are made according to drawing, they can be manufactured as planned. While performing the analysis, unfavorable tolerance buildup, unnecessarily close tolerances, and tolerances which would require special or complicated inspection and testing devices should be noted and discussed with design engineering for possible modification.

Stage 6—Trial run before placing the new design into production.

It is advisable to run a trial lot through the factory and, if necessary, make special studies that can be a basis for further improvement of the design. Where the trial run is made using tools, fixtures, gauging and testing devices intended for formal production, the component parts should be inspected and tested for important functional dimensions and characteristics, and the results tabulated to see if the specified tolerances are satisfactory for trouble-free production. The number of units for the trial lot depends on the size and cost of the units and the yearly production requirements. Analyzing the results of a trial lot is an excellent method for controlling and predicting the performance of future production lots. The records obtained should be made available for future reference to inspection, test, manufacturing engineering, and design engineering, to act as a guide in setting limits for establishing a quality product. These records should also be reviewed to determine if the quality levels and performance meet customer requirements.

Incoming Material Control

Incoming material control involves the receiving and stocking, at the most economical levels of quality, of only those materials whose quality conforms to the specification requirements.

Incoming material may come from:

- outside vendors, or
- other components within the company.

These materials are usually ordered in two ways:

- through purchasing, where outside vendors and other company components are involved, or
- through production, where orders are issued to other sections or units within the departments.

Each method of ordering results in material that conforms to certain specifications for manufacturing, assembling, or product design—all at a reasonable quality cost.

Let's look at a picture of quality control engineering contributions in this area.

Stage 1—Request to purchase material.

Quality control engineering can contribute at this stage by advising the purchase of materials which meet quality requirements and by recommending the use of vendors rated as reliable. This information can be obtained from any of the pertinent special process studies, analysis of quality records, vendor rating plans, and vendor quality evaluations.

Stage 2—Order placed on vendor.

Quality control's contributions at this stage are to advise the vendor through Purchasing of the quality level expected, and to inform him of the means of product evaluation, and the type of sampling plan to be used at incoming inspection. Quality control should also arrange for some form of vendor certification that will help assure the desired quality level. A visit to the vendor's plant should be considered, depending upon the importance and complexity of the part or product.

Stage 3—Material received.

Contributions at this stage consist of furnishing instructions concerning the proper sampling procedures which will quickly and efficiently determine the quality level of incoming material, and to take appropriate steps for corrective action where needed. Accurate record-keeping at this stage will supply information that can aid materially in classifying vendors according to their ability to supply satisfactory material. When this information is properly tabulated and classified, quality control engineering can work with purchasing and production to assist them in using the services of vendors who consistently supply satisfactory material.

Stage 4—Forwarding the material.

The various statistical tools used in the product control activity will assist the quality control engineer to contribute in this final stage of incoming material control. The control routines will indicate whether or not the material is satisfactory, and this information can be relayed back through purchasing to the vendor. If the material is not satisfactory, further analysis of factory problems using statistical tools will indicate the reason why and will assist in making the proper disposition of the material.

Product Control

Product control involves the control of processed parts and assemblies at the source of production so that departures from the quality specification can be forestalled before defective parts are produced. Included in this activity are the manufacture and assembly of parts and products, the inspection and testing of these parts and products, and their packaging and shipment.

Now let's look at a picture of quality control engineering contributions in this activity.

Stage 1—Receipt, examination of requirements, and release of order.

At this stage, quality control engineering can assist design and product engineering in establishing quality levels by means of the quality audit, and quality cost and tolerance analysis tools. It can assist in equipment selection through process capability studies of machines, tools, jigs, fixtures, etc.; this will assure that the equipment is capable of producing parts within the specifications and will simplify the actual controlling of the job during manufacture.

Stage 2—Material in process of manufacture.

Here, the quality control engineer can make his biggest contribution to the product control activity—the control of parts and products in in-process manufacturing. Control charts, inspection planning, and sampling plans are the tools available to him. This is the stage where the efforts applied on the two previously discussed activities—new design control and incoming material control—will begin to pay dividends. The better the job done prior to product control, the easier it is to establish and maintain controls during manufacture.

Stage 3—Final approval of product.

The contributions at this stage consist first of helping to ascertain if the established levels of quality have been met and, second, to determine average outgoing quality levels. In addition, it is important that quality results be analyzed and fed back to the appropriate functions so that some benefit can be derived from the mistakes or omissions encountered in the control set-up. This analysis can also be used to establish customer quality certification plans.

Stage 4—Packaging and shipment.

Quality audits at this stage will verify the quality of the product being shipped to our customer. Feedback of this information to appropriate functions for corrective action will greatly assist in improving the quality level and will point out where best to apply future efforts.

Special Process Studies

This activity relates to the intense critical surveys and tests conducted to locate the specific cause of quality problems and to determine information that will lead to improving product quality. Of particular importance here is the fact that the information acquired about today's quality problems can be applied to tomorrow's production—again, to prevent poor performance and costly delays.

These studies are directed to major, usually nonrepetitive, quality problems that could occur at any stage in the whole manufacturing cycle, and could be related to any one or all three of the previously mentioned quality activities. They are not confined to quality problems originating in the factory, but can be used for many of the major investigations initiated by engineering, methods, and other groups to determine the feasibility of improving quality standards on existing products or facilities. This is where the quality control engineer makes full use of statistical methods, as these studies can involve the use of a simple distribution analysis study or the more complex designed experiment type of analysis.

One important method is the process capability study. In General Electric, we have developed a unique method for calculating a process capability. We take a specified number of samples from a controlled process and enter their measurements on a process capability work sheet. Through a simple addition, totals are obtained which are then registered on the G.E. quality control slide rule.* We then read directly the process capability on the appropriate scale of the rule. This information is then recorded on the work sheet which serves as a record of the limitations of the particular process studied.

The G.E. quality control slide rule can also be used to calculate sigma—in addition to calculating control

*See *Industrial Quality Control*, Vol. XI, No. 8, May 1955, p. 62.

limits for percent defective and fraction defective control charts—without the need for solving involved formulas.

So, this new approach to quality control is directly dependent upon the results it produces through quality control engineering. The measuring sticks used may be drawn from a wide variety of elements, depending upon the plant situation. These may be reduction in complaint expenditures, reduction in manufacturing losses, improvement in design and in manufacturing processes, reduction in product cost, improvements in quality-mindedness, reduction in extra costs and increased customer satisfaction. The results can be most effectively presented to management through quality cost analysis and product quality audit.

In summary, therefore, organizing for effective quality control depends heavily upon a quality control engineering activity which develops quality activities from the inception of design through the receipt of the product by a satisfied customer, and so realizes the two important objectives of quality control—quality assurance and optimum quality costs.

Quality Control, Industrial Engineering, and Operations Research

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Thomas Carlyle, the philosopher, once said, "The purpose of education is not knowledge, but action." The purpose of this article is not to increase your knowledge, but to excite you to action. It is not a discourse on techniques, but a challenge—a challenge to men in the industrial engineering and quality control fields to meet management's needs, not tomorrow but today.

Reading some of today's literature, one would gather that an industrial engineer is a rather dull fellow who can manipulate a stop watch and is constantly taking time studies and making process charts. Further, he is purely a shop man and is unaware of such things as interdepartmental coordination, sales quotas, human aspects, organizational theory, policy decisions, and, of course, is never allowed to look at operating statements and only speaks to department heads when he receives his ten-year pin.

On the other hand, I often hear a quality control engineer spoken of as an ex-inspector who has somehow become exposed to statistical theory and is constantly running around posting and looking at control charts, all the time muttering that no one appreciates his work and that if only the production and engineering departments would listen to him and not look at him as an inspector in sheep's clothing he could immediately set the operation right.

You and I know that these concepts are untrue, but don't let yourself think that they are not real impressions that must be overcome by demonstrated proof to the contrary. It is natural to resent the narrow scope attributed at times to quality control and industrial engineering, but one can't fail to be aware of the reasons. In the first place, many company managements don't realize that the approach and professional skills of the industrial and quality control engineer are applicable to almost all management problems and are not confined to shop production and inspection functions. This is not altogether their fault because much of the work being done, the nomenclature, trade articles, and our very titles lead them to the conclusion that we are primarily concerned with shop processes.

Secondly, too many men in the field have specialized in the repetitive use of certain techniques and concentrated on refining small pieces of the over-all industrial or business process. No wonder management gets to thinking of them as methods men, time study men, chart men, or quality inspectors. Those industrial or quality control engineers who do visualize the broader use of their tools, and there are quite a few, often contend they can't get to use them due to managements' restrictions on their scope, their organizational status, etc. Sounds like a vicious circle, doesn't it? Well it is until, in a given situation, something breaks it.

The recent growth of the operations research, or systems engineering, concept is timely because it is going to help break that circle and jar many an industrial engineer, quality control engineer, and executive from the comfortable ruts which they have shaped for themselves.

Operations research (or whatever you want to call it) is going to represent different things to each individual and company depending on how they have used and combined the various concepts and tools of scientific management. From our experience with it I think of OR as one part management engineering, one part statistical quality control, a drop of higher mathematics, mixed well by a team of men operating on a problem with their heads in the clouds, their feet on the ground, and no holds barred. Oh, I almost forgot—plus lots of time and a healthy budget.

My first experience with operations research was in 1944 when, as director of operations for the Second Air Division, an operations analysis

group was attached to our headquarters, headed by a doctor of mathematics from Harvard. The doctor did not bring an electronic computer with him; only a piece of paper, a pencil and a slide rule. He did not use any fancy mathematics but got to work correlating the bombing accuracy of our groups to the formation which they were flying at time of release. Also, of extreme interest to us at the time was his calculation of the chances of being hit by enemy fighters in a particular type of formation.

It is pointless to argue what is new about operations research or whether it is merely industrial engineering or quality control dressed up in a new suit and digging deeper into bigger problems. What is important is your taking whatever is new in the concept to you as an individual and using it to broaden your outlook, give new meaning to your skills, and excite you to add new tools to your kit. The complexity of managements' problems today requires the best that quality control, industrial, or research engineers can contribute. It has already been conceded that probability and statistical theory are the most important single tools of OR. However, the broader a problem, the less important becomes the tool and the more important the attitude, imagination, experience, and ability of the individual involved.

So don't worry about what your present title is or what certain types of work are supposedly called. If you catch the spirit—go to it—and let the results speak for themselves.

Although management's need for these new concepts and broader use of tools is very real, don't expect your executives to suddenly tap you on the shoulder and say you're just what the doctor ordered; you've got to sell and prove their worth.

Reflect that management, too, has become concerned over the rapidly diminishing returns resulting from the continual refinement and adjustment of their existing work processes, organization, and equipment. They are beginning to sense that changing attitudes, needs, and hardware call for periodic overhauls of the whole process. The complexity of such a task and its implications are causing them to gradually realize the need for ways of measuring and understanding the true nature of their entire operation.

I say "true nature" because many executives are becoming aware of the fact that of all reports, statistics, and financial figures they see, very few are designed to tell them in a timely way precisely what is happening and why. They are beginning to realize that very little material is gathered to enable management to manage, most of it is to tabulate what different functions of the company believe to be a measure of results.

Also, the increasing size, complexity, and cost of doing business is placing a bigger premium on each major decision and at those times the lack of understanding, facts, and over-all measurements make them realize how little they have on which to base their judgment. In extremely critical decisions of a long-range nature, they dream of a way to test the alternatives and in some way forecast the varying probability of success.

The appearance of high-speed computers and data processing equipment on the scene has raised their hopes for getting the right information on time and being able to release the energies of a large percentage of their personnel for higher skilled work. The fact that one out of every five workers in the United States is engaged in paper work is of serious concern.

It looks like a set up, doesn't it? Well don't be fooled. Managements, like you, have to be sold and shown by examples how most of their needs can be met by the imaginative application of the very tools in our kits.

To me, an industrial engineer and quality control engineer, have a lot of knowledge and experience to exchange. More industrial engineers must become acquainted with the natural laws of variation, probability, and their infinite application. Likewise, quality control engineers should learn the all-important scientific approach to special problems and develop a feel for methods, organization, and the problems of human beings at work. Maybe I am suggesting a coalition; it makes little difference. Ultimately, it all will depend on the individual and his interests and abilities. You can be sure there will be enough work for both.

To give you an idea of how we in United are utilizing the varying approaches and techniques of industrial and quality control engineers, let me explain our set up.

First of all, the Industrial Engineering Department in United reports to a non-operating administration headed by a vice president—the Vice President of Economic Controls —who also has as his responsibility such things as market research, economic forecasts, airplane schedules, and cost control. We in industrial engineering provide an internal consulting service to the rest of the company in all fields of management engineering. The little card which we proudly issue to our prospective clients sets forth the following:

- We specialize in isolating and defining problems and offering specific solutions for your decision
- Time, objectivity, a trained approach, and all the tools of scientific management are at your service
- We respect our clients' confidences and carefully consider the human aspects of each problem
- Services available on request but subject to current commitments to other clients and programs.

Our clients include the president, members of the general staff, department, division and section heads. Some of the services which we offer are as follows:

1. Management Studies
2. Special Surveys
3. Organization Studies
4. Methods & Work Simplification
5. Work Standards
6. Quality Control
7. Operations Research
8. Planning & Programing
9. Facility Planning
10. Job Evaluation
11. Job Analysis
12. Form Design
13. Regulations
14. Incentives

Now let's see how we are organized to do our job. There are five groups: organization planning, work analysis, regulations & forms, quality control, and operations research. Under work analysis we have facility planning, standards, methods, and special projects. We do not worry too much about formal organizational lines but, depending on the project, bring together those men who have the skill to best attack the problem at hand. Although we must serve over 16,000 people in the company, our goal is not to see how big we can get but how good a service we can render. Our aim is to provide the company with those skills and tools which it would be unable to get in any other way; to provide an impartial and objective viewpoint

when necessary, and to introduce and train other people in the use of new management tools. We make a conscious effort to multiply ourselves by continual training programs in methods, quality control, work simplification, etc. Other than our standards setting job, if any phase of our work gets repetitive or routine, we find a way to turn it over to an operating administration.

As a result of our organization planning responsibilities, we have been able to establish quality control groups in our operating administrations and assist them in developing programs which they administer. This leaves our staff superintendent of quality control, who is responsible for sparking our company-wide quality control program, free to develop new applications and techniques, and to train staff and supervisory personnel.

We firmly believe that the more people we expose to the basic theories of probability, sampling, and the natural laws of variation, the more productive and understanding they will become in their own tasks. This process takes time because the average accountant's, engineer's, and supervisor's background and education rest pretty firmly on empirical concepts and the use of averages and fixed values.

To illustrate the scope of our quality control activities and how we try to apply statistical technique wherever we can, here are a few examples of some of the projects that are or have been worked on.

- A work sampling check on a large shop in our Maintenance Base to determine the reasons for a low utilization on standards.
- A sampling of supervisory activities in the Accounting Department to determine distribution of effort.
- A six months' experiment between three major airlines testing the use of sampling techniques to settle interline accounts. We feel this and similar applications are going to start a revolution in the accounting field because many are beginning to realize that "inductive accounting," as one man called it, is often more accurate than 100 percent verification.

In July of 1954 we decided to undertake a full blown operations research approach to our system aircraft routing and maintenance problems. Because we felt we were basically familiar with many aspects of the approach and had never been restricted in tackling over-all company problems regardless of where they led, we decided to strike off on our own. This was done, however, only after we had talked to several consulting firms and research organizations, and had scanned reports of OR work. Since then, in talking to various people at computing and research centers, we find that we have a major project by the tail.

The project basically concerns itself with the whole process of providing serviceable aircraft to meet schedules over our 13,250 mile system. This naturally leads into performance, location of facilities, manpower scheduling, maintenance plans, flight delays, etc. Our objective is to determine the true nature of our existing operation and then provide management with station and system models on which to test their ideas and plans.

As members of the team, we picked a top notch aerodynamicist with a good background in higher mathematics from our engineering department in San Francisco and a 25-year veteran in the flight operations field from the flight dispatch manager's group at our Denver Operating Base. Recognizing the importance of statistical techniques, we assigned our staff superintendent of quality control and, in addition, an industrial engineer who had worked on procedural and systems problems.

After nine months we all agree with Morse and Kimball that the most important single mathematical tool of operations research is probability and statistical theory. Little has been written on the problems of a team approach to a really complex business problem, but we feel as though we already have enough material for a book. Much of the work is routinely time consuming, involving decisions as to what material is needed, how it can be collected, collecting it, deciding on how it will be analyzed, making test analyses, and problems of hand vs. machine computation.

Always there is the need to balance the varying viewpoints of the team members, to keep the project from digging too deeply here or passing over too lightly there. Getting the material needed and making sure it is without bias is quite a problem in itself.

Enough about the OR project—let's take a look at where we are. We've talked about how other people look at the industrial and quality control engineer, the need for and application of our skills to higher level problems, the impact of OR, and how one company is trying to approach its opportunities in these fields.

Remember that the purpose of this article was not to increase knowledge, but to spark action. Maybe this list of do's and don'ts will prove of value.

1. **Don't** let titles or the nomenclature of the day narrow your vision as to the job that you can do or which needs doing. Quality control has been dancing with inspection, and industrial engineering with production, for so long they both have almost missed some very attractive partners.
2. **Do** try and grasp the impact of your statistical and probability skills—their application to almost every problem. But don't fall for the fatal fascination of techniques as such—they mean nothing unless they are imaginatively put to work.
3. **Don't** be confused by the mathematical jargon of operations research or systems engineering—you have their basic tools in your kit. Concentrate on assimilating what's new in concept and approach.
4. **Do** undertake an application of your skills to a problem off the beaten path—no matter how small—even on your own time or for someone in another department. If it's good, let them have the credit. Soon you'll be getting requests and recognition of your skills. Then is the time to submit your proposal for an attack on a bigger management problem and you're on your way.
5. **Do** try to spread the word—exchange ideas and experiences.

Here is your challenge and your opportunity! Everything in the universe is subject to the natural laws of variation. You who have the tools of measurement and prediction must demonstrate their application to management problems and other fields of endeavor with imagination and understanding.

An Over-All Quality Assurance Plan*

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IN considering any quality assurance plan, the over-all objective of quality assurance should be kept constantly in mind. This objective, as conceived in Bell Telephone Laboratories where the term "quality assurance" originated, is to provide continuing assurance to the customer-user (the operating telephone company) that the product which it accepts is at a level of quality which it reasonably expects. Thus quality assurance is primarily a function exercised in behalf of the customer. It embraces much more than inspection or quality control or a combination of these.

Defined in this manner, quality assurance to be effective must

(1) Establish quality standards which, from the point of view of the customer, represent product which is satisfactory, adequate, dependable, and economic.

(2) Continuously evaluate product quality in terms of these standards.

(3) Initiate measures to prevent any significant departures of product quality from these standards, and

(4) Present continuing evidence as to actual product quality.

Successful attainment of these four goals requires the exercise of a number of closely integrated activities by an organization which has both a sufficiently authoritative status and a suitably designed internal structure. The quality assurance plan briefly described in this article is the outgrowth of some 30 years' experience with the quality assurance program as carried on by Bell Telephone Laboratories on behalf of the entire Bell System.

For purposes of convenience and clarity, the major activities of the quality assurance plan can be listed under the following six headings.

- Setting quality standards
- Preparing inspection practices
- Disposing of non-conforming material
- Handling engineering complaints
- Conducting quality surveys
- Analyzing, evaluating, and reporting quality results

It is extremely important to bear in mind that while these activities are listed separately, they are so closely interrelated that the incorrect or inadequate administration of one of them jeopardizes the value of all the others, and of the plan as a whole. Thus in Fig. 1, they are shown grouped in a circle. As we consider each activity separately, we must keep in mind the qualifying effect of each of the others. This is illustrated schematically in the chart by arrows which indicate the contributions and qualifying effects of each of the five other activities upon the preparation of inspection practices.

Setting Quality Standards

Since our over-all objective is to assure to the customer a product whose quality is at the level which he expects, we must

(1) define what is meant by quality, and

(2) ascertain what quality level the customer expects.

We must, in other words, establish suitable quality standards. Many of these are expressed in the form of specific over-all numerical measures. Some may be merely implied.

One approach to setting specific quality standards might be to assume that the design specifications, to which the customer buys the product, both define the quality and specify its level. Broadly, this is true. But the specifications do not usually define acceptable standard of workmanship, and workmanship is surely one characteristic of quality. Again, the specifications ordinarily define merely the limiting quality for an individual specimen—a composite of values expressed as a maximum or minimum or both. The customer expects, on the average, something better than permissible extremes. Often we cannot determine specifically the quality of the actual product as furnished—measurement may be destructive. Or the dictates of economy in inspection may enforce sampling which, in turn, involves risks and defect tolerances. For one reason or another it is necessary to have quality standards which are closely related to, but which are normally not specifically covered by, the specification requirements. Design specifications generally concern individual units of product. Quality standards for quality assurance purposes relate to quantities of units or product as a whole.

Quality standards may be expressed in one of several forms. A common one, and perhaps the oldest, is percent defective. This is a simple measure in terms of the proportion of product departing from specified requirements but it does not differentiate between serious and minor deviations. Standards in terms of demerits per unit, wherein any deviation is assigned a demerit value commensurate with its seriousness, do so differentiate, although they are subject, of course, to the masking effect inherent in composited measures. Where individual characteristics are sufficiently important, standards are usually established directly for those characteristics and, when they are measurable characteristics, in terms of measured

Figure 1—Major Activities of Quality Assurance

*Presented at the Ninth Annual ASQC Convention, New York, N. Y., May 23, 1955.

values of those characteristics—capacitance unbalance in cable pairs, for example. Other types of numerical measures are frequently used as standards. Thus we may decide that a standard level of quality for soldered connections is represented by one defective connection in 10,000.

The customer wants the highest quality he can get up to the point where the cost of any improvement in quality represents more than the improvement is worth. When all pertinent factors are considered, this is equivalent to saying that the customer wants the highest quality consistent with over-all system economy. Thus in setting the quality standard we must try to reconcile all pertinent factors: the costs of production (including inspection), installation, operation, and maintenance; the effect on the useful life of the product; and the effect on the service to the public. Discussions with development, production, and operating company people, and a review of the information afforded by the other quality assurance activities, furnish the background for such reconciliation and for the ultimate setting of the quality standard.

Preparing Inspection Practices

Inspection represents the traditional approach toward ascertaining and insuring product quality. Inspection per se need not be, nor is it in the Bell System, a quality assurance function. But the evaluation of inspection results and the verification of their pertinence and reliability are definitely a part of the quality assurance program. Thus, while the Quality Assurance Department performs no actual inspections, it does prepare or approve the inspection practices by which the inspections are performed and the results made available for quality assurance purposes. It stipulates, moreover, that these inspections are to be performed by an inspection agency which operates with the customer point of view and which has no responsibility for production or costs or schedules. The Quality Assurance Department verifies, by quality survey, to be discussed later, that the inspection results thus obtained are reliable.

To be most effective and economical, inspection procedures should be tailor-made to suit the circumstances. Some products, in the interests of a particular factor such as safety, economy or reliability, require individual practices. Rubber gloves, a safety item, is an example. Others may be treated as family groups, with special provisions for any necessary variations within the group covered in the one practice. Electrolytic capacitors are an example. In any event, the acceptance criteria in the practice should be compatible with the quality standards for the product.

The aggregate of products currently purchased or manufactured by Western Electric Company for the operating companies represents over a billion dollars annually. Thousands of different products are involved, ranging from transistors to telephone poles, or from relays to radio transmitters. About 800 different inspection practices have been prepared to cover the inspection of these products. As one might expect, they employ most of the known procedures for inspecting product and for specifying acceptance criteria: sampling by attributes and by variables; 100 percent inspection; single- and double-sampling lot inspection plans; continuous sampling plans; check inspection plans; lot tolerance and AOQL plans; criteria based on percent defective and demerits per unit as well as on average and range; control chart techniques; and so on. Underlying the preparation of each of these practices is a forecast of the expectable quality history of the product at the time it is presented for acceptance: how it was manufactured; whether any kind of quality control techniques were applied; how, by whom, to what requirements, and by what equipment it was inspected. Upon information of this character largely depend the particular type of inspection procedure to be employed and the nature and quantity of inspection results called for.*

Disposing of Non-Conforming Material

Occasionally, even under manufacturing conditions involving good control of quality, individual lots of product are encountered which are non-conforming; that is, they fail to meet the acceptance criteria incorporated in the inspection practices. If the deviations are serious or affect large quantities of product, the non-conforming product must, of course, be junked or repaired. In many cases, however, the non-conformances are marginal; the acceptance criteria may be exceeded by only a small amount or the deviations from requirements may be minor. Many requirements in the design specifications are such that marginal departures from these requirements in the product may have little, if any, noticeable effect on service or life. In the long run, if the supplier stays in business, the customer pays the cost of rejected material. In some circumstances urgency of demand may be an important factor. It is to the customer's advantage to accept occasional lots involving minor non-conformances.

The acceptance of non-conforming material on behalf of the customer is a quality assurance function. The quality assurance department sets the quality standards, prepares the inspection practices, and handles the engineering complaints. It is in the best position to determine, with the advice of other organizations and of the customer himself if necessary, whether acceptance or rejection of non-conforming product is in the over-all economic interest. Specifically the quality assurance engineer is responsible for the relationship between the acceptance criteria in the inspection practice and the quality standard for the product. He is thus in the best position to determine the effect of accepting the non-conforming lot.

Handling Engineering Complaints

When the customer receives product which fails to meet specified requirements, fails to function as intended, or fails to provide reasonable life in service, he may enter an engineering complaint. The number and character of engineering complaints received provide a sort of negative index of quality—negative in the sense that complaints indicate possibily poorer quality than was intended, and also in the sense that the absence of complaints does not necessarily indicate satisfactory quality. Complaint handling is a valuable source of information for quality assurance purposes in that complaints often disclose otherwise unsuspected shortcomings in design or manufacture. Moreover, the number and nature of the complaints provide a rough measure of the satisfactoriness of the standard quality level and of the mechanism used to insure this level. One might ask why, if all proper quality safeguards are effective, there should be any complaints at all. It is doubtful that it would be possible to insure against the receipt of any justified complaints, and if it were, the necessary safeguards would be so costly

*In a subsequent issue of *Industrial Quality Control*, H. F. Dodge and M. N. Torrey will discuss one of the inspection procedures widely used to cover product manufactured in large quantities by processes that are normally well controlled; see "A Check Inspection and Demerit Rating Plan."

as certainly not to be in the most economical over-all interests of the system. The quality situation can be a perfectly healthy one, if the number and seriousness of complaints is kept within reasonable limits.

Investigation of a complaint involves the finding of the cause of the difficulty, recommending remedial action for the specific case at hand, recommending action to prevent recurrence when the economics of the circumstances warrant such preventive action, and assigning responsibility—the latter forming the basis upon which the Western Electric Company, the supplier, may make credit adjustment if such is involved. Our method of handling complaints varies with the character of the defect reported, the extent to which it prevails, and the value of the material involved. The quality assurance department maintains a staff of field quality engineers who are located throughout the United States at points selected best to serve the operating companies. These men are trained to determine the causes of a wide variety of operating company difficulties. They are, moreover, in a position to make investigations on the spot where such difficulties arise.

Some 50 percent of all complaints entered by the operating companies represent more or less isolated occurrences involving small monetary value such that satisfactory, prompt, and economical handling is accomplished by treating them essentially as claims. For convenience in complaint accounting we classify such complaints as Class 2. In these cases the local Western Distributing House, from which the operating company obtains its product and to which it sends the complaint and the defective product, merely obtains the agreement of the Laboratories' local field quality engineer and makes an adjustment in the form of replacement or credit.

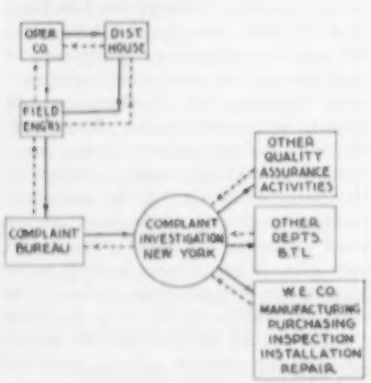

Figure 2—Engineering Complaint Flow Chart

There is the possibility, of course, that a condition, which from the viewpoint of one local area may appear to be an isolated occurrence, may actually be duplicated in other areas to the extent that it represents in the aggregate a situation which warrants treatment as more significant from a quality standpoint. To guard against the hazard of overlooking such cases, arrangements are in effect whereby the details covering all complaints handled on a Class 2 basis are reported to New York where they are carefully reviewed to determine whether further investigation and action are warranted.

The remaining 50 percent of the complaints are more involved and necessitate more extensive investigation. Some of these—about one in five—can be handled by the local field engineer who is able to diagnose the cause of the difficulty, assign responsibility for the condition, and handle the complaint himself. We classify such complaints as 1A. Here again arrangements are in effect whereby the quality assurance engineers are kept informed of the details of all such 1A complaints handled by the field engineers so that the significance of the sum total of all similar complaints can be evaluated, and further steps taken if warranted.

As would be expected, when we consider the wide variety of materials, apparatus, equipment, and circuits employed in the telephone plant, not all complaints can be settled on the ground by our local field quality engineers. Some 40 percent of all complaints entered by the operating companies relate to conditions which, because of the specialized skill or testing equipment involved in their diagnosis, or the magnitude of their over-all effect on quality, warrant direct reference to, and handling by the quality assurance engineers. We designate these types of complaints as Class 1. It is these complaints, in particular, from which we derive information leading to changes in design, production procedures, and in the quality standards, inspection practices, or non-conformance policies of the Quality Assurance Department itself. The close relationship which the complaint activity bears to the quality assurance function makes it obvious why the handling of engineering complaints should be, and is, a quality assurance activity.

Figure 2 illustrates the flow diagram for complaints. Arrows leading to and from the right of the circle, "Complaint Investigation New York," indicate requests to, and information from, various sources, and recommendations for remedial action by responsible organizations.

Conducting Quality Surveys

The quality survey has been characterized as the most important single cog in the quality assurance machinery. It comprises an over-all review of all factors relating to the quality of a particular product, to the end of determining what the quality should be, what it is, and what must be done, if anything, to get the quality where it should be and to keep it there. Since the quality assurance activities themselves—such as the handling of engineering complaints, the preparation of inspection practices, and the disposition of non-conforming material—have a very important bearing on the quality of the product, the correctness and effectiveness of these activities are examined, as well as the activities of other organizations.

The survey is conducted by a survey committee usually consisting of three people—one member from the quality assurance organization who acts as chairman (he is an engineer, who is a quality specialist on the particular product under survey), one member from the independent inspection operations organization of the Western Electric Company (the inspection agency which provides the Quality Assurance Department with Inspection information covering the product), and one member who represents the inspection function of the manufacturing, installation or repair organization, whichever is involved. Each of these members, as preparation for the formal conference which is usually held at the manufacturing plant, reviews thoroughly those factors relating to quality with which he is most directly concerned and, hence, most familiar. The quality assurance member's activity in this connection is indicated in the left hand column of Table I. Through his preliminary study and from all the quality information available to him as background, he endeavors to determine whether the over-all quality setup is designed in a manner most likely to result in optimum over-all system economy, and to insure that the various means necessary to reach and maintain the proper quality level are continuingly effective. He notes for further investigation and action any circumstance which does not appear to be consistent with this over-all objective.

Each of the other committee members, in the meantime, reviews those quality related activities which are within his particular field of interest or responsibility. The inspection agency member, for example, reviews the performance of its inspectors, the degree to which the specified minimum inspection sample requirements are met, the accuracy and maintenance of the test sets and gauges employed in its inspection, the degree of compliance with specified non-conformance routines, etc. The production inspection member similarly reviews the methods, instrumentalities and records covering the shop inspections.

After each member has completed his preparation work, he issues a preliminary report which describes what he did and what he found, together with his picture as to the significance of his findings from a quality standpoint. He sends a copy of his preliminary report to each of the other two committee members for their review prior to the formal conference.

The three committee members meet at the manufacturing plant for the formal conference, the date for which appears in a schedule established well in advance. As indicated in the right-hand column of Table I, the committee discuss their respective findings, selecting for further attention those which appear to warrant specific corrective action. They jointly make a tour to review the manufacturing processes by which the product is made, on the lookout all the while for any circumstance which appears inconsistent with the desired quality of product, whether it be in the content of the process specifications or the actual operations as carried on. Similarly they review the shop and inspection agency inspection plans and actual procedures. They pay special attention to the type of gauges and test sets employed, the manner of their use, and the means and frequency with which they are calibrated and maintained. Bear in mind that the quality assurance organization relies on the representativeness and the over-all integrity of the inspection agency's inspection results, and must be satisfied that these results are in all respects equivalent to those which the quality assurance people themselves would obtain if they were to perform the inspections. Any irregularity either of omission or commission which this shop tour discloses is noted.

With all this information as background—the preliminary report findings, the conference discussion and the shop tour—the committee jointly prepares a survey report which describes the quality of the product in relation to the quality intended, cites any circumstances incompatible with this quality intent, and recommends to the organization responsible any measures which the committee feels necessary either to obtain or to maintain quality at the desired level. These recommendations are referred to as "action items," and may involve a change in design, a revision of a specified limit, a modified sampling technique, an improvement in manufacturing process and so on. In a separate memorandum the committee lists, for the informal attention of those involved, any minor discrepancies such as drawing errors, which do not affect quality.

Copies of the survey report are sent to interested organizations in the Laboratories and in the manufacturer's plant—in particular to those to whom items have been assigned for action. The committee continues to follow up these items until action is taken in a form which satisfies each of the three committee members. Thereupon the action item is closed.

TABLE I—Activities Associated With a Quality Survey

Preparation For Conference	*Survey Conference At Plant*
Study of Laboratories' specifications and drawings	Compare notes among Committee members
Comparison of manufacturing drawings with Laboratories' engineering information	Review manufacturing processes
Examination of product sample	Review inspection plan and procedures
Request for Field Engineers' comments	Examine gage and test set maintenance records
Study of complaint background	Prepare Survey Report
Review of inspection practices	Prepare memorandum covering minor findings
Review of inspection results—adequacy, quality levels, nonconformances	Refer Recommendations To Responsible Organization
Review Field comments	Follow Up and Close Action Items After Committee Agreement
Prepare and distribute Preliminary Reports	
Review Preliminary Reports of other Committee members	

Survey subjects are selected for their timeliness from a quality standpoint as evidenced by the complaint history, the inspection results, and the number and nature of nonconformances. The importance of the product in terms of the nature of service it is designed to provide, the quantity of output, and its monetary value are, of course, major factors in the selection. All major items of product are covered, and repeat surveys are made on a cyclical basis at time intervals consonant with the importance of the product and the likelihood of its becoming subject to quality degrading influences.

Analyzing, Evaluating, and Reporting Quality Results

This is the activity in which is gathered together all of the quality information furnished by all of the other activities, the inspection results are analyzed, and the reports on product quality prepared. Important products, over 200 of them, are quality-rated individually. Important types of associated groups of apparatus—crossbar, step-by-step, station, etc.—are combined in overall rates. Various types of systems and representative individual central offices are also rated. Finally, the composite quality of all products furnished to the Bell System is rated on a quarterly quality index basis. Different rating procedures are employed for the individual products, following, of course, the type of measure used for the corresponding quality standard. A few examples of quality measures used for rating are illustrated in Fig. 3.

Included in the quarterly quality report are not only the individually important and over-all rates, but also significant comments on quality arising from the other quality assurance activities—notably engineering complaints and quality surveys. Copies of the quality report are distributed to management and to the various organizations which have a primary interest in, or responsibility for, product quality.

Quality Assurance Organization

Production people are faced with the obligation to maintain low costs and to meet close schedules. Similarly, design engineers, especially in these busy times, are under heavy pressure to get designs into production with a minimum of time and field trial. The quality assurance organization has no responsibility for design or production, for costs or schedules. Its function is to evaluate product quality and to initiate

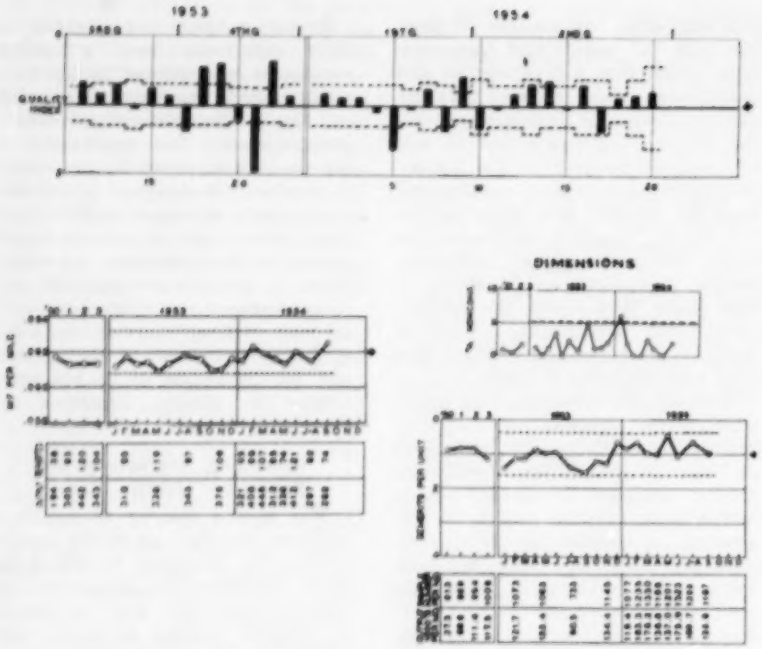

Figure 3—Examples of Quality Measures Used in Rating

action toward the removal of any quality shortcomings, actual or potential. It is thus in a particularly favorable position to act judicially. To do so, it must be fully independent of, and have authority fully equal to, those with whom it does business. Should its status permit overruling except by authority higher than design, production and quality assurance and except on the basis of factual merits, the benefits to be gained from an independent, unprejudiced, critical judgmenft are lost. It should be emphasized that no small part of the success of the quality assurance effort in the Bell System is attributable to the complete freedom and full authority with which its activities have been carried on.

The quality assurance activities are, as will have been noted, largely engineering—engineering with a particular slant, perhaps, and with a better than usual appreciation of the laws of probability, statistical distributions, and quality control—but nevertheless engineering. Hence about 85 of the total of slightly over 100 people in the Quality Assurance Department are engineers and their technically trained assistants. A dozen or so are women college graduates with mathematical and statistical training; and about a half dozen are clerical people. The close coordination among the various activities, which is vital to the success of the whole quality assurance program, is possible only if we provide for a high degree of communication. Our organizational setup insures this.

Figure 4 shows a skeletonized functional organization of the department. At the left will be noted a heading "Quality Specialists." About half of the entire personnel is in this category. Each one of these specialists is an engineer highly trained with respect to his specialty—a particular type of telephone product or a group of closely similar products. He is responsible for all phases of quality assurance associated with his specialty. He handles all the engineering complaints, passes upon all non-conformance cases, determines the inspection practices to be followed (with any necessary assistance provided, as will be explained later), sets the quality standards, supervises the analysis of inspection results, and conducts all quality surveys on his specialty. Thus each specialist is essentially Mr. Quality Assurance insofar as his particular product is concerned. Most of these men have had long experience with their respective products; many of them have been recruited from Laboratories' development departments. By having one man responsible for all phases of quality assurance on his particular product, we insure the close coordination of the various activities. In our judgment this organizational plan of having a single individual responsible for all phases of quality assurance with respect to each major specialty is the most important single factor in the success of the quality assurance plan. In fact, we are convinced that the plan cannot be made to work successfully without this feature.

In addition to being engineers with supplementary training in statistics and quality control, these men must also be pretty good diplomats. When we have in mind that a large part of their work involves finding, and calling attention to, the shortcomings of others, we can appreciate that they are in a good position to find themselves disliked unless they exercise a considerable degree of diplomacy.

A second, and much smaller, group in the department is that shown on

Figure 4—Organization of Quality Assurance Department

the chart under the heading "Quality Methods Development." These are people highly trained in the theories of statistics and quality control. In this group have originated the basic concepts of the control chart, defect tolerances, consumer's and producer's risks, and scientific sampling plans. They represent in a sense the development and research group in the department. They are responsible for the development of new theories and techniques of sampling, quality rating and quality control. They prepare technical memoranda to cover both the theoretical and practical aspects of these various subjects, including such things as single, double and multiple sampling tables, charts for setting up continuous sampling plans, methods for computing quality indexes and control chart criteria therefore, mathematical tables for use in computing operating characteristics of sampling plans, etc. These technical memoranda are made available to the various manufacturing plants in the Bell System and are of assistance to the quality specialists in the discussion of shop inspection procedures that are reviewed in the course of quality surveys.

Frequently the engineers in this group are consulted by the quality specialists for assistance and advice concerning the best methods of sampling and quality rating. They insure that the inspection practices and quality rating procedures are uniform and consistent from a statistical point of view; prepare certain of the more general types of inspection practices; consolidate the several quality rates associated with the various types of products; and plan and edit the over-all quality report which has been mentioned. They also, jointly with the quality specialists, cooperate with the development departments in establishing engineering requirements, to the end that verifying inspections will be facilitated and product quality best insured.

The field engineers, who man the 15 field engineering offices throughout the United States, have already been mentioned. As has been indicated, they are located at points designed best to serve the twenty-odd operating companies. Their functions and activities have already been discussed.

Under the heading "Complaint Bureau" is a small group of clerical people who handle the filing and records covering the engineering complaints and the technical correspondence of the department, and prepare the periodic complaint report.

Conclusion

From the foregoing description, it is evident that our over-all quality assurance plan represents a "cradle to grave" process of target setting, information gathering, evaluation, and corrective action—an integrated feed-back arrangement administered by a group of specialists in a carefully designed organization which is, itself, part of the plan—all directed toward obtaining and maintaining a quality which represents an optimum in dependability and economy.

Installation of a Quality Control Program

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Introduction

To start a quality control program is not easy *with* the blessing of top management and almost impossible without their full support. Personnel introducing and administering a quality control program in any organization must be missionaries, as well as salesmen possessing the virtues of patience, perseverance and versatility. Every new application will offer a new problem and rules of procedure must be formulated as conditions dictate.

Before we start talking about establishing a quality control program, we should determine why such a program is desired. Regardless of what product a company manufactures, or what service it renders, all have reasons of their own for starting a quality control program. Whatever the many reasons may be, without a doubt at least one ranks very high on the list; namely, cost. The most important item in modern business and industry is controlling production costs and quality control is a very important means of doing this.

In the early days of the industrial era of this country, there were relatively few competitive manufacturing firms. Through reinvestment of earnings, these firms increased the output per man-hour, lowered their prices, increased their volume, and enjoyed the prosperity that invited competition. As the number of competitive firms increased, the necessity for the control of production costs increased. The firms that were successful in the control of their production costs survived. Those that did not appreciate the importance of the problem, or failed to find a satisfactory solution to it, became business casualties.

It should be noted that the term "quality control" and not "statistical quality control" was used. Quality control is all inclusive whereas statistical quality control is one of a number of different methods of achieving it. Statistical quality control is used in conjunction with inspection, static testing, production engineering, nondestructive testing, as well as other methods, to achieve quality control. As an example, McDonnell Aircraft Corporation utilizes optical inspection, radiography, fluoroscopy, magnetic particle inspection, leak test, fluorescent penetrant inspection, electric current conduction tests, spectrochemical analysis, hardness testing, ultrasonic inspection, as well as statistical quality control within the Quality Control Department.

Quality control, in its broadest sense, refers to the systematic control of those variables encountered in a manufacturing process which affect the excellence and cost of the end product. Such variables are a result of a combination of men, materials, and machinery necessary to the process of manufacturing. Quality control is never absolute; it is always relative to certain other considerations. For one thing, the word

quality is meaningless unless the end use of the product is also stipulated. The term "good quality" means that the article is good for the purpose for which it was intended. Quality is an abstract word unless related to definable and measurable characteristics of the product involved.

Quality is likewise related to the economics of manufacturing. The degree of quality that can be maintained under a designated manufacturing process, the percentage of imperfect goods, if any, that are acceptable to the producer and/or to the consumer—these are typical of the economic considerations linked with quality control.

Although the precepts of quality control have been in existence for some time, it has only been recently that industry generally came to see the potentialities of its methods for the solution of production problems. In the past decade industry has seen a tremendous advance in the preciseness of its quality standards. Quality control has changed from a generic art to a specific science complete with definite standards and devices for measuring product characteristics against those standards. Characteristics such as hardness, surface finishes and noise, to mention only a few, have in recent years become measurable to great exactness on specially designed instruments. Thus has industry been required to adapt itself to rapidly developing quality standards, measuring equipment, and control techniques. Furthermore, its manufacturing technology has time and again been taxed to keep pace with the ever higher degree of precision demanded by advances in the science of quality.

Quality Attitude

Positive quality attitudes in a plant are primarily represented by the very intangible but extremely important spirit of "quality-mindedness" extending from top management right through to the men and women at the bench. Such attitudes will not automatically develop through the mere installation of a quality control program. They must be earned through action by members of the quality control organization and through the results gained from activities in the quality control jobs.

These attitudes can be earned through what may be described as essentially a process of responsible "selling" by the proponents of quality control. Whatever is new about the quality control program is gradually and successfully introduced step by step to the entire plant organization so as to obtain its willing acceptance, cooperation, and participation. New and strange quality control routines are not introduced in the shop without considerable fore-warning and smoothing of the way; descriptions of quality control technical methods are not worded in the mysterious language of the mathematician or technologist but are presented in shop terminology.

Selling of the quality control program is basically a matter of sound human relations activity—it is not a technological issue.

Planning and Selling

The first task to be accomplished when installing a quality control plan is to develop a concrete, practical, salable plan outlining the ultimate objectives. At least four general considerations must be taken into account during development of this plan.

- An essential requirement is that the plant's quality needs should first be carefully analyzed. The quality control plan being introduced should be one whose routines and terminology are tailored to the individual factory requirements determined from this analysis. It should not be a "prepackaged" program lifted bodily from another plant or from the literature in the field.

- The scope of the quality control activities recommended by the plan should be based upon sound economic analysis rather than developed without reference to the economics of plant quality needs. This scope should be determined by striking a balance between the range of the quality problems in the factory and the cost of the minimum amount of control required to face and solve them.

- The quality control plan will undoubtedly recommend action and co-operation from many functional groups and individuals in the plant. The support, involvement, and motivation of these individuals and groups are far more likely to be secured if they have participated in formation of the plan and of the quality control program it recommends.

- The plan should emphasize the tangible benefits that may be derived from quality control and should indicate the measuring sticks that will be regularly used in the program to evaluate the results produced.

Acceptance of the proposed quality control plan by top management, with whatever adaptations and improvements it wishes to make, is an essential without which no further genuinely effective selling can be done in the factory. The approval may well be tentative, with complete acceptance contingent upon the results from initial quality control applications.

When the plan has been accepted by management, tentatively or otherwise, a sequence of several steps should be followed to bring its proposals into actual operating reality in the plant. This sequence will develop the plan through the stage where widespread tangible evidence will be available to all members of the plant organization on the actual value of quality control activities.

There are various ways to introduce a quality control program, but the method that was used at McDonnell Aircraft will be discussed.

Introduction at M.A.C.

It would be in order, at this time, to mention a few statistics concerning McDonnell Aircraft Corporation to enable the reader to better understand the approach to this problem that was used.

McDonnell is the largest individual employer in the St. Louis area with approximately 15,500 employees. Of this total number of employees, approximately 1035 are in the Quality Control Department.

Today's fighter airplane is an extremely complicated mechanism which requires the integration of some 30,000 pieces into the efficient weapon required by the armed forces. Approximately 18,000 different items are procured from some 1500 vendors which supplements the fabrication and assembly shops. Engineering changes are numerous because in peace time the emphasis is on quality rather than quantity.

The company spent in excess of $750,000 last year for training employees. Participating in this training program, which included on-the-job training as well as supplementary training taken by an employee on his own time, were 5,387 individuals.

During the years 1951, 1952 and 1953 a total of 803 inspector trainees were processed. The inspector training program is a 13 week course during which the trainee is paid to attend classes.

It can be seen from these statistics that fairly large groups of people are involved, so personal contacts or verbal instructions are not practical.

Early in 1950, the inspection department first became genuinely interested in the use of statistical techniques. When top management was approached, it soon became apparent that the new concept that was being presented was not going to be accepted with open arms. Neither did top management shut the door on the ideas. Instead it was urged to proceed slowly and continuously in the approach to the use of SQC at MAC. Arrangements were made for a series of five lectures to be given by Dr. Nadler of Washington University during June and July, 1950. By prearrangement, the lectures were for selling purposes and not for technical instructions. Some of the supervision from our manufacturing division, engineering division, purchasing department and inspection department were persuaded to attend. The lectures were specifically intended to stimulate interest and get people in the organization talking quality control. The series of lectures served their purpose very well as people started talking and asking questions. The Technical Library was then stocked with many text books on statistical quality control and everyone was informed that they were available for their use.

About this same time an intensive advertising campaign was started. Arrangements were made with the Elliot Service Company to furnish weekly posters dealing with quality which were prominently displayed throughout the factory. Photographs and articles were published in the company monthly newspaper relating to quality and quality control. Articles from various national publications were distributed to some of the personnel who were important to convert. It is realized that these methods are very intangible and their worth impossible to evaluate accurately, but subsequent events have shown them to be beneficial and to have had a real effect.

Personnel Inventory

In the meantime, it was decided that before going very far, it would be necessary to take a personnel inventory. It would be useless to try to set up a statistical quality control organization if the people who were to administer it were incapable of understanding it. After a certain amount of research, it was decided that for the factory working level there were only two basic characteristics that needed to be measured. These were the IQ of an individual and his knowledge of simple arithmetic. Two standard tests were given to the inspection personnel, including supervision. As was to be expected, a very good normal distribution curve resulted when the test scores were plotted. By comparing these results with standard test scores, the conclusion was reached that about one-third of the personnel would not be able to absorb the study of statistical quality control. Based upon the philosophy that no one can adequately administer any function without knowing and understanding the basic precepts, it was decided to use the inspectors only for recording the results of their inspection and that all data would be tabulated, interpreted, and plotted by staff personnel especially trained in SQC.

Training

It was then decided that the time had arrived to formally start the training program. Arrangements were made with the University to offer a 30-hr. course in SQC at the factory for inspection supervision. This instruction was taken by the individuals of their own volition on their own time. It should be pointed out that it was felt to be imperative to train the supervisors of the inspection department before attempting to train others. With intent, however, two shop supervisors were included. These two were chosen because it was felt that their departments offered the most fertile fields for the initial attempts in SQC. If these two people could be convinced early in the program, considerable shop co-operation could be attained. It subsequently worked out as was hoped, and one of these shop supervisors has become of great influence in the quality control program.

Two staff personnel from the inspection department, who are graduate engineers were then sent to a ten-day intensive course in statistical quality control. One of these individuals was later sent to Purdue University for an advanced course in SQC and he became the instructor for later classes offered to all personnel interested in the subject. He subsequently trained approximately 150 people through the supplementary training program.

Infiltration

About this time it was decided to start collecting data in a few departments and charting it but not distributing this information. After a suitable period had elapsed, the shop general foremen of these departments were called in and shown these charts. Eventually they began to evidence interest and requested weekly copies of these charts, which was exactly what was desired. The shop supervision gradually realized the value of a graphical representation of the quality level of their departments and accepted the suggestion of posting large versions of these same charts in their departments in such locations as to enable the workmen to see their trend. The majority of the American workers have a pride in their work and these charts serve to attain better quality by appealing to this pride through a graphical presentation of the results of their work. Phenomenal results were achieved in some departments. Rivalry developed between departments and the workers themselves as well as the assistant foremen started checking their work before presenting it to inspection. It must be admitted, however, that many charts that were started did not show the proper kind of picture within the activity that they represented and it was necessary to discard them. Some of the shop supervision did not react favorably to the approach of the quality control personnel, and in these cases the fault was undoubtedly that of quality control supervision in not having made the proper diagnosis of the specific situation.

Several items, worthy of note, should be mentioned.

(1) These charts are used for reporting quality trends and not for acceptance purposes. This is not because we did not have faith in statistical methods but because of the nature of airframe work and because certain inherent peculiarities caused us to deem it inadvisable. We now feel that we are ready to introduce sampling methods in some of our operations which we intend to start in the near future.

(2) The charts in use were started at different times. The moral of this is do not bite off more than you can chew. One successful application is worth more than many inconclusive attempts.

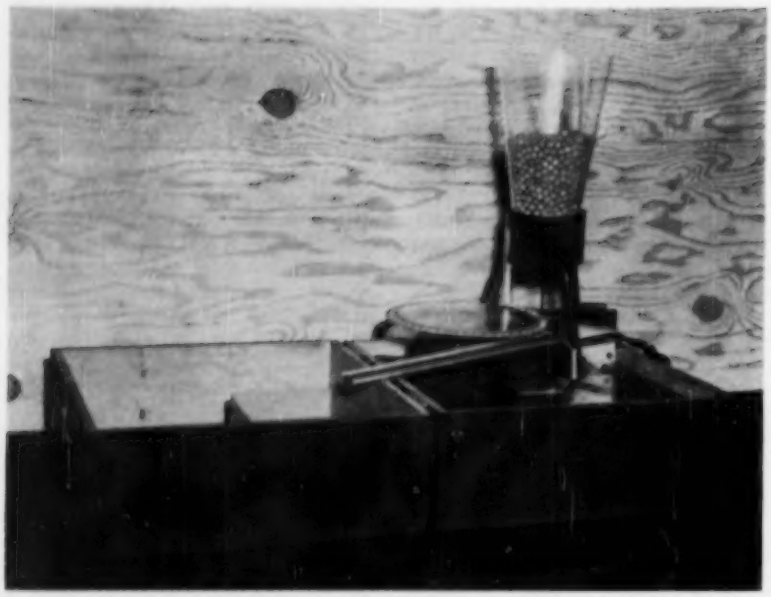


Figure 1—Visual Fatigue—How long can you see what you should?

Figure 2—Laws of Chance—Do you really have a chance?

(3) In that our charts are used for reporting purposes and not for acceptance purposes, calculated control limits are not employed. We use a "Target Limit" which is an arbitrary level of quality set by the shop general foreman for his own department. We feel that this procedure is of much greater value because the calculated control limits would be governed by the quality of the work produced and would vary accordingly. The "Target Limits" are progressively lowered as the quality improves.

(4) Never force a new procedure on the shop but persuade them to try it. If it proves successful, convince them that it was their idea. If it fails, accept the blame.

Training Aids

Early in the program, we started to accumulate various devices to be used for demonstration and training. None of these devices were conceived by us but full credit belongs to others who were kind enough to furnish us literature regarding their construction and use. We have found that nothing holds the interest of the average American as well as a gadget. The value of devices of this type cannot be over-emphasized. Their full value is not realized from their academic applications but principally from their advertising ability.

A very effective method of demonstrating to a group that 100 percent inspection is not infallible is through the use of these two simple sentences.

NO. I

FEDERAL FUSES ARE THE RESULT OF YEARS OF SCIENTIFIC STUDY COMBINED WITH THE EXPERIENCE OF YEARS.

NO. II

DON'T LOOK FOR PREMIUMS ON COUPONS AS THE COST OF THE TOBACCO BLENDED IN CAMEL CIGARETTES PROHIBITS THE USE OF THEM.

These sentences are shown, one at a time to groups for a period of 30 seconds. The group is asked to count the number of times the letter "F" appears in sentence No. I and the Letter "E" in sentence No. II. Records were kept of the results and for over 200 individuals only 16 percent got the correct answer for sentence No. I which has six "F's" and only 32 percent for sentence No. II which has eleven "E's."

Another item that we found very useful is shown in Fig. 1. This device is another method of demonstrating that 100 percent inspection does not remove all of the defectives. The inspection lot consists of 3000 10-mm wooden beads with a 2-mm hole through each. One hundred of the beads have steel drill rod pins pressed into the 2-mm hole. Two hundred of the beads have wooden plugs pressed into the holes, while the remaining 2700 have nothing in the holes. Those 100 with the steel pins inserted are considered to be defectives.

The beads are placed in the plastic hopper which fits into a metal base. The beads drop into holes in a revolving turntable moving at a speed

of 2 rpm. The turntable has 50 holes drilled at equal intervals around its circumference which will therefore present 100 beads per minute to be observed by the inspector. The beads roll on a felt track approximately one quarter revolution of the turntable which permits the inspector to observe the entire surface of each bead. The beads then drop into a chute which deposits them in a container. The effectiveness of the inspection can be determined by passing a strong magnet over those beads passed by the inspector. Any defectives that got past the inspector will be picked up by the magnet because of the steel plug. Then, by passing the magnet over those beads removed by the inspector as being defective, it can be determined if any good beads were erroneously rejected. This demonstration employs two of the most common detriments to good inspection: monotony and fatigue. Since the inspector must concentrate his full attention on the beads for 30 minutes without a break, he is likely to become careless before the test is completed because of constant repetition.

This test was given to 50 people, on whom data were tabulated, resulting in scores of from 16 percent to 100 percent with the average being 72 percent. Included in the group tested were inspectors of various classifications, engineers, clerks, and supervisors. No correlation could be made between the scores and the type of work the individual normally did. The only conclusions that could be drawn from this are that human error invariably exists and that regardless of the individual's specific training, 100 percent inspection will not remove all defectives.

The demonstration that generated the most interest among our personnel was the slot machine shown in Fig. 2. We used this before groups or in SQC classes by selecting one individual and giving him a specified number of nickels to play the slot machine in whatever manner he wished. The pay-off, when a winning combination is selected, is in the form of slugs with various monetary values stamped on their faces that cannot be put back into the machine because of a difference in size. In this way, when the individual's nickels are exhausted, the loss can be calculated. An explanation is then given to the group of the odds against the player for the various combinations. The same individual is then given the same number of nickels and again permitted to play as he wishes. However, he now will take advantage of the most favorable odds and invariably he will lose less money this time. You can be sure that the player will never win with this "one armed bandit."

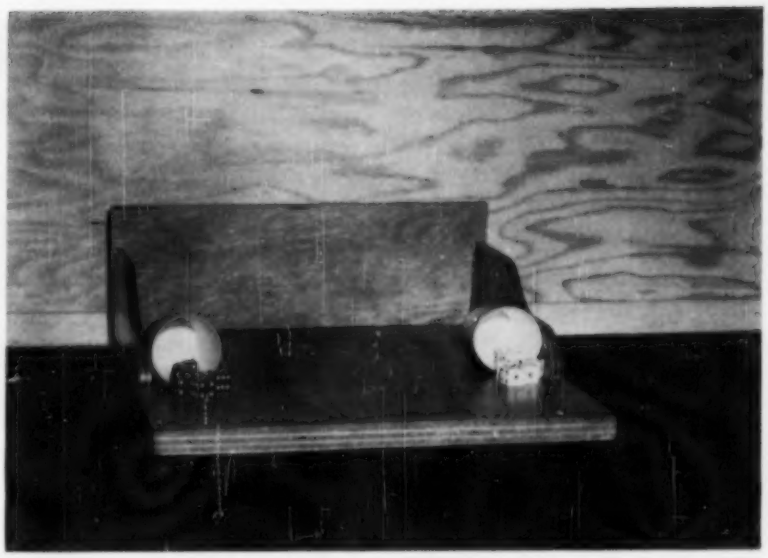


Figure 4—Are the laws of chance a gamble?

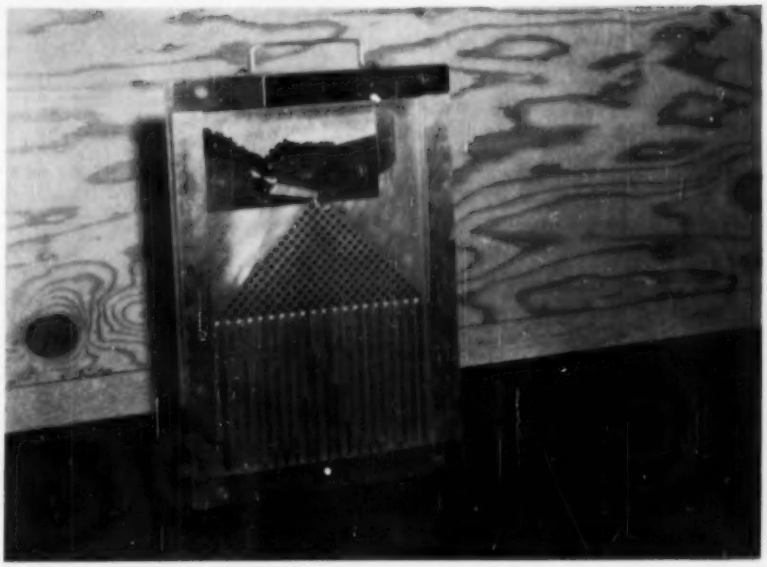


Figure 3—Frequency Distribution—Is it normal? The key to control.

Another item, which we purchased from the Timken Roller Bearing Company, is the "Quincunx" which is shown in Fig. 3. This device demonstrates very well how a normal, bell-shaped, distribution will invariably be produced if left to a constant system of chance causes. It can also be used to show how an assignable cause will produce something other than a normal distribution.

Figure 4 is another popular demonstration which uses two sets of dice. Each set has six dice with one set being honest and the other somewhat unorthodox, having two sixes, two fives, one four, and one three on each dice. The object of this demonstration is to show that an X, R control chart will indicate when the unfair dice are substituted for the fair dice even though the person plotting the chart does not see the dice. The dice are thrown, the spots on the upper faces totaled, and this figure given to a person, out of sight of the dice, to plot on the control chart. In this way, if each set of dice are thrown for a minimum of three times, the person plotting the chart can ascertain when the unfair dice are used. This is accomplished by

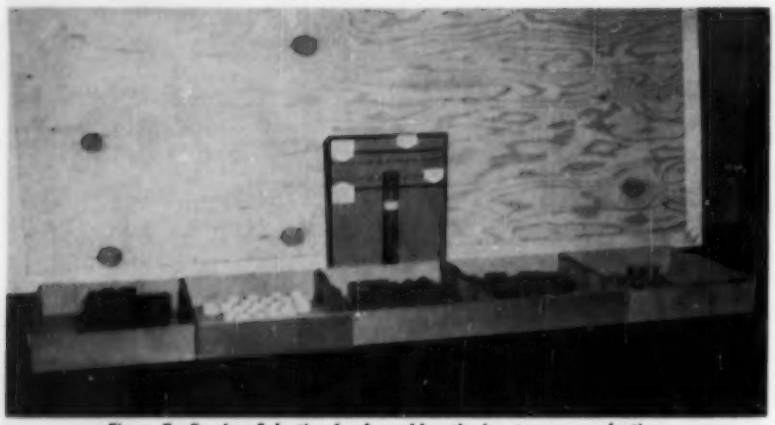


Figure 5—Random Selection for Assembly—the key to mass production.

using 13.7 for the lower control limit and 28.3 for the upper control limit. The effectiveness of these control limits serves as a good illustration for the function of $\bar{X}$, R charts in manufacturing operations.

A demonstration intended primarily for the personnel who design the product is the one shown in Fig. 5. Certain overall tolerances must be held in the design and manufacture of an assembly. These tolerances are usually divided among the component parts in such a manner that an assembly made entirely of parts of minimum size or of maximum size will be acceptable. This means that the sum of tolerances for the individual parts is equal to that of the assembly. This demonstration shows that when component parts are made by a quality-controlled process and are selected for assembly at random, the tolerances of the individual pieces may be larger than are normally provided by the engineering department. This, of course, would provide more latitude for the shop in its manufacturing procedures.

The equipment consists of 100 pieces of tubing of different lengths, in five groups of 20, with each group painted a different color. The differences in length of the tubing within any one group amount to as much as one inch. A board, mounted on a base with two solid lines spaced 3⅛ inches apart and two dotted lines spaced 1½ inches apart is used to stack against it one randomly selected tube from each group which thus measures the effect of combining tolerances. The two solid lines represent the height the tubes reach if either the longest or the shortest of each group is selected. The two dotted lines represent where the tubes will reach 997 in 1000 if a random selection is made. The regularity with which this demonstration works as it is intended is uncanny and it is a very convincing demonstration.

We have numerous other gadgets which we used such as a plastic bowl (see Fig. 6), for demonstrating single, double and sequential sampling, control limit calculators, etc. It is worth repeating that we have found devices of this nature to be very effective when used in conjunction with training programs. "One picture is worth a thousand words" is an adage best able to describe their value.

Conclusion

The following, in brief, summarizes our feeling toward SQC:

1. SQC is well worth while for any industrial organization to install, regardless of the item it manufactures or the volume it produces.
2. A much healthier relationship is developed between inspection and manufacturing personnel through the installation of SQC.
3. SQC offers another means to impress the manufacturing personnel with the truism "Take care of quality and quantity will take care of itself."
4. Statistical quality control cannot be installed in any organization over night, but a lengthy educational program is required both prior to starting any phase in the factory and indeed throughout its entire existence. A premature beginning, before the personnel affected understand the uses and limitations of SQC can harm the program to the extent of its possible defeat.
5. An individual from within your own organization must be trained in SQC so as to be capable of teaching others. It is highly desirable for the person instructing others to be completely familiar with the problems of your business. This has both a real and a psychological effect as to how others accept the training.
6. Never install SQC throughout an organization simultaneously. Start gradually and modestly in that department most likely to show beneficial results and take advantage of the results obtained to further the selling aspect. It is far more desirable to have shop supervision request that SQC be set up in their departments than to tell them that they must accept it.
7. Point out to management, whenever the occasion permits, that SQC is primarily for their benefit as a tool of industry. Keep the fact constantly before management that inspection can be conducted without SQC but the control of quality cannot. Factual evidence should constantly be presented to management showing the benefits of the SQC program. In other words "Blow Your Own Horn" modestly—but blow it.

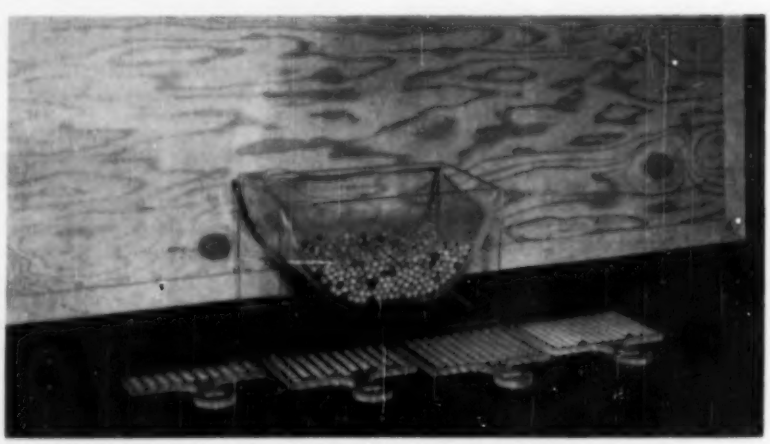
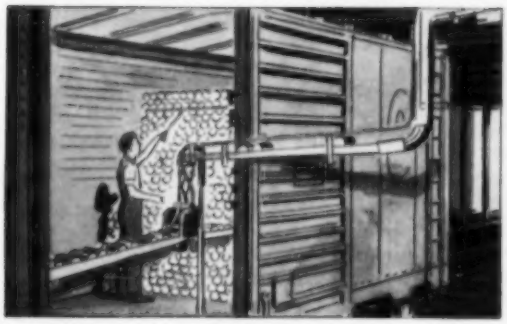
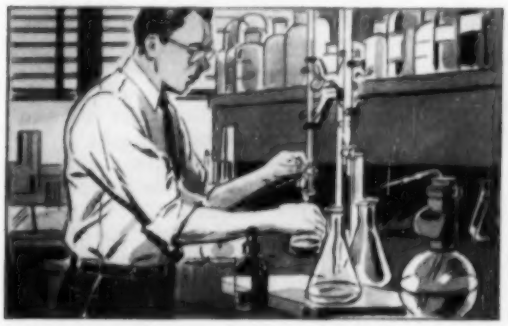


Figure 6—Sampling—Fishing can be selective.

Three keys to Continental's packaging quality



MEN—All operations in the manufacture of cans or other Continental containers require trained men. Even the loading operation gets constant study to improve quality of our tailor-made service.



MATERIALS—A second key to packaging quality at Continental is our continuous search for new and better materials... as well as study of ways to make more efficient use of present materials. Quality performance is the goal.

MACHINES—Continental engineers are constantly improving the machines we make for use by packers and processors, as well as our machines for manufacture of cans and other containers. Here, too, quality is all important.

MEN

MATERIALS

MACHINES

Every Continental package is tailor-made for the needs of the product it protects. This would be a simple assignment, except for two factors: The container must be made as cheaply as possible because the ultimate consumer is buying "contents," not "packaging." At the same time, the packer must have dimensionally-true containers that will travel through filling and sealing machines at speeds from 400 to 1200 a minute without a hitch.

This means that high quality is basic to Continental's every operation, in men, materials, and machines, which produce the containers themselves.

CONTINENTAL CAN COMPANY

Eastern Division: 100 E. 42nd St., New York 17
Central Division: 135 So. La Salle St., Chicago 3
Pacific Division: Russ Building, San Francisco 4

TAILOR-MADE PACKAGE SERVICE

Studies In Textile Testing

NORMAN R. GARNER

U. S. Naval Powder Factory, Indian Head, Md.

TEXTILE testing procedures are usually so complex that it is frequently impractical and probably too costly to attempt to investigate all the possible sources of variation with one statistically designed experiment at any one time. On the other hand, experience has shown that not using statistical designs is also impractical and costly. So to compromise, the testing procedure can usually be subdivided into major categories for which a statistically designed experiment is feasible. Then, if the program is conducted under expert technical surveillance, and if the data generated by the statistical design are evaluated with cognizance of this surveillance, much knowledge can be obtained with respect to desired objectives. The following experiments were performed based on this philosophy. They were conducted under the supervision of the General Testing Laboratories, Philadelphia Quartermaster Depot, during 1952 and 1953. They are summarized very briefly and only the statistical aspects of the designs and the analyses of the results are presented. The computational methodology can be found in the textbooks listed under the references.

TABLE I

A—Analysis of Variance Model, If Interaction Present

Variation due to	d. f.	Expected Mean Squares
Strips	7	$\sigma_e^2 + 12\sigma_s^2$
Operators	2	$\sigma_e^2 + 32\sigma_o^2$
Machines	3	$\sigma_e^2 + 8\sigma_{om}^2 + 24f$ (Machines)
O × M	6	$\sigma_e^2 + 8\sigma_{om}^2$
Testing Error	77	σ_e^2

B—Analysis of Variance Model, If Interaction Not Present

Variation due to	d. f.	Expected Mean Squares
Strips	7	$\sigma_e^2 + 12\sigma_s^2$
Operators	2	$\sigma_e^2 + 32\sigma_o^2$
Machines	3	$\sigma_e^2 + 24f$ (Machines)
Testing Error	83	σ_e^2

Tensile Tests

The first experiment concerns the tensile strength of textiles on the Scott testing machines. This test can be subdivided into two major categories, operators and machines. The operator effect includes the details of preparation of samples for testing and the mannerisms of testing, whereas the machine effect includes all its aspects, such as speed, calibration, and component parts. As a natural consequence, we assume the operators to be a random selection from a "larger population" of operators, whereas the machines constitute the entire population and no bias should exist amongst them. Thus, the experiment is to obtain an estimate of the variation between operators and to test whether the machines, in toto, are equivalent.

As in most experiments of this nature, consideration must be given to the variability of the material tested, which for this experiment is Uniform Twill, Type I. (To conserve expenditures, cloth which was available without further cost was used for experimentation and control purposes.) This cloth was available in 4-in. rolls which created a problem of a one-way elimination of heterogeneity. However, it was believed that a 4-in. strip of Uniform Twill, 100 in. long (warp wise) could be considered homogeneous. That is, the tensile strength in the warp direction over a strip 100 in. long would have a minimum amount of variability between samples taken from the strip. With four machines to be tested and three operators available the experimental procedure briefly, was as follows: Select, at random, eight 4 x 100 in. strips from the available cloth and cut into sixteen 4 x 6 in. samples. Each operator picked four of these at random, and tested one each on the four machines. Thus, each operator tested one sample from each strip on each machine. This consumed only 12 of the 16 samples available from a strip. The other four samples were kept in reserve in case an "improper" test was observed by the technical observer. All tests were conducted under specified environmental conditions.

It was not known whether or not there might possibly be an operator × machine interaction, which would be interpreted as the failure of each operator to react the same for each machine. If this interaction is present the analysis of variance model would be as shown in Table IA. If it is not present it would be as shown in Table IB, where f(machines) denotes the additional effect to the expected mean squares due to biases between fixed effects, if they exist.

TABLE II—Tensile Strength of Uniform Twill, Type I
(Observed Tensile Strength Minus 180 Lbs)

	O_1				O_2				O_3				Strip Sums
	M_1	M_2	M_3	M_4	M_1	M_2	M_3	M_4	M_1	M_2	M_3	M_4	
S_1	18	7	5	9	12	16	15	9	18	13	10	22	151
S_2	8	21	11	6	16	4	21	19	25	13	19	12	164
S_3	7	11	11	1	7	14	12	6	17	20	19	20	145
S_4	6	4	10	8	15	10	16	12	10	16	12	18	137
S_5	10	8	6	10	17	12	12	22	18	16	21	22	174
S_6	7	12	3	15	18	22	14	19	18	23	22	14	187
S_7	13	5	15	16	14	18	18	9	16	16	10	15	165
S_8	1	11	8	12	7	13	11	13	15	14	14	11	130
O × M Sums	71	69	70	74	106	109	119	109	137	131	127	134	
Opr Sums				284				443				529	
Opr Avgs	6.9							13.8				16.5	

Machines	M_1	M_2	M_3	M_4
Sums	314	309	316	317
Averages	13.1	12.9	13.2	13.3

The interaction component is not in the expected mean square for operators since we are concerned with the variation between operators for these four machines only, whereas it does enter into the expected mean squares for machines since we wish to test for differences between machines for all operators. The data are summarized in Table II.

To determine which model to use we first test for the presence of interaction as shown in Table III. Since the F-ratio is less than one, we assume that there is no interaction present and conclude that operators are equally efficient on all machines. Thus, the analysis of the data is according to Table IB and is given in Table IV.

Since the mean square for machines is less than testing error mean square we assert, at least provisionally, that the machines are equivalent. The estimates of the standard errors are: testing error,

$$\sigma_e = \sqrt{18.20} = 4.27 \text{ lbs};$$

between operator,

$$\sigma_o = \sqrt{\frac{482.82 - 18.20}{32}} = 3.39 \text{ lbs};$$

between strips,

$$\sigma_s = \sqrt{\frac{30.76 - 18.20}{12}} = 1.02 \text{ lbs}.$$

Hydrostatic Pressure Test

A similar subdivision of operators and machines can be made for the hydrostatic pressure tests made on the Suter hydrostatic testing machines. This test measures the effectiveness of water repellant. Briefly, the test is as follows: After securing a sample specimen of the cloth (approximately 1 sq. ft.) in the machine, water pressure is applied at a constant rate by either a foot- or hand-operated lever until the operator observes three droplets of water which have penetrated through the cloth. The pressure is relieved by the same levers and the amount of water pressure consumed is measured. Thus, in essence, the operator effect is the ability of the operator to observe three droplets of water and his reaction time from the time he observes these water droplets to the time he relieves the water pressure.

For this experiment it was believed that the water repellant applied to the cloth could be heterogeneous over a small area of cloth lengthwise (warp direction), width wise (filling direction) or in both directions. Thus it was necessary to account for heterogeneity two ways. No interactions of any kind were expected. Thus, with four machines, four operators and a possible two-directional heterogeneity of the water repellant it was decided to use a 4 x 4 Graeco-Latin Square design. A strip of Water Repellant Cotton Oxford approximately 52 in. wide by 200 in. long was available. Since one replicate of the experiment consumed 48 × 48 in., and since there was quite some concern about the manner of variation of the water repellant, the experiment was replicated four times. The four replications were in succession along the cloth warpwise. The design layout and the yields (measured in inches of water rise up a cylindrical tube with a radial area of 1 sq. in.) are shown in Table V. The analysis and expected mean squares are shown in Table VI.

The estimate of standard errors are, $\sigma_o = 1.13$ in., $\sigma_m = 0.79$ in., $\sigma_r = 0.28$ in. and $\sigma_e = 0.41$ in.

The machine averages are:

1 : 39.84 in.

2 : 39.88 in.

3 : 41.13 in.

4 : 41.28 in.

Machines 1 and 2 are hand-operated whereas 3 and 4 are foot-operated. If we segregate these means into groups by Tukey's method,[4] we can say that machines 1 and 2 which may be alike, are different from machines 3 and 4, which may be alike. Apparently the reaction time is quicker with the hand than the foot.

It is to be noted that three of the 12 degrees of freedom for rows within reps represent variation between four strips of cloth. The remaining nine degrees of freedom represent a reps × rows interaction. If we decompose this source of variation accordingly we have mean squares for rows of 1.625 in. (with three degrees of freedom) and 4.769 in. (with nine degrees of freedom) for reps × rows. It appears we can infer that the water repellant is not applied very homogeneously even over a small segment of the cloth.

Further, note that the averages for replications, in the order numbered, are 40.09, 40.19, 40.82, and 41.03 in., respectively. It appears as though a trend exists; however, it would not be appropriate to generalize this conclusion.

TABLE III—Testing for Presence of Interaction for Tensile Tests

Variation due to	d. f.	S. S.	M. S.	F-ratio
O × M	6	19.11	3.19	< 1
Testing Error	77	1491.67	19.37	

TABLE IV—Analysis of Variance for Tensile Tests

Variation due to	d.f	S. S.	M. S.	F-ratio
Strips	7	215.33	30.76	
Operator	2	965.64	482.82	
Machines	3	1.58	0.53	< 1.
Testing Error	83	1510.78	18.20	

TABLE V—Design and Yields of Hydrostatic Pressure Tests

Rep I				Rep II				Rep III				Rep IV			
A	B	C	D	B	A	D	C	C	D	A	B	D	C	B	A
1	3	4	2	2	4	3	1	3	1	2	4	4	2	1	3
40.0	43.5	39.0	44.0	39.0	39.0	40.0	41.0	41.0	38.5	39.0	43.0	43.0	40.5	43.5	39.5
B	A	D	C	A	B	C	D	D	C	B	A	C	D	A	B
2	4	3	1	1	3	4	2	4	2	1	3	3	1	2	4
40.0	42.0	40.5	38.0	36.5	42.5	40.5	38.5	41.0	38.5	41.5	41.0	41.0	39.0	39.5	41.5
C	D	A	B	D	C	B	A	A	B	C	D	B	A	D	C
3	1	2	4	4	2	1	3	1	3	4	2	2	4	3	1
42.0	40.5	38.0	40.0	40.0	39.0	41.5	41.5	39.5	42.0	41.5	42.0	42.0	41.0	40.5	37.5
D	C	B	A	C	D	A	B	B	A	D	C	A	B	C	D
4	2	1	3	3	1	2	4	2	4	3	1	1	3	4	2
40.0	36.5	39.0	38.5	41.5	39.5	39.0	44.0	41.5	41.0	40.5	41.5	40.5	42.5	44.0	41.0

LEGEND
Operators A B C D
Machines 1 2 3 4

TABLE VI—Analysis of Variance for Hydrostatic Pressure Tests

Variation due to	d. f.	S. S.	M. S.	F-ratio	Expected Mean Squares
Replications	3	10.218	3.406		
Columns within Reps	12	29.964	2.497		
Rows within Reps	12	47.808	3.984		
Operators	3	33.843	11.281		
Machines	3	29.091	9.697	7.55	
Testing Error	30	38.490	1.283		
Total	63				

TABLE VII—Yields for Dynamic Absorption Test of Water Repellant Cotton Oxford —Percent Gain by Weight (Yield—42.00%)

Laundry	Test	Rep I	Rep II
A	A	7.20	9.06
	B	11.70	11.79
	C	15.12	14.38
	D	8.10	8.12
B	A	2.40	2.14
	B	7.76	7.76
	C	6.13	6.89
	D	2.64	3.17
C	A	2.19	2.69
	B	4.92	1.86
	C	5.34	4.88
	D	2.47	1.86
D	A	1.22	2.43
	B	2.62	3.90
	C	5.50	5.27
	D	2.74	2.31
	Sums	88.05	88.51

TABLE IX—Two-Way Table of Averages— Dynamic Absorption Tests

		TESTINGS				
		A	B	C	D	
LAUNDERINGS	A	8.13	11.74	14.75	8.11	10.682
	B	2.27	7.76	6.51	2.90	4.860
	C	2.44	3.39	5.11	2.16	3.276
	D	1.82	3.26	5.39	2.52	3.248
		3.666	6.538	7.938	5.514	5.514

TABLE VIII—Analysis of Variance for Dynamic Absorption Tests

Variation due to	d.f.	S.S.	M.S.	F-ratio	Expected Mean
Main Plots					
Reps	1	0.0067	0.0067		$\sigma\omega^2 + 16\,\sigma\epsilon^2$
Laundries	3	298.3299	99.4433	125.306	$\sigma\omega^2 + 4\,\sigma\alpha^2 + 8f(L)$
Main Plot Error (A)	3	2.3808	0.7936		$\sigma\omega^2 + 4\,\sigma\alpha^2$
Sub-Plots					
Testings	3	102.9102	34.3034	60.023	$\sigma\omega^2 + 8f(T)$
T × L	9	26.8700	2.9855		$\sigma\omega^2 + 2f(TL)$
Sub-Plot Error (B)	12	6.8589	0.5715		$\sigma\omega^2$

Dynamic Absorption Test

The last example concerns the dynamic absorption test. The primary purpose of the experiment was to show factual evidence that a particular laboratory was not evaluating the dynamic absorption test equally to a standard laboratory. After consideration of a detailed description of the testing procedure, it was found feasible, because of the complexities involved, to separate the experiment into two major divisions; the laundering effect and testing effect. The laundering effect would include all aspects of laundering and drying; the testing effect includes preparation and conditioning of sample prior to actual determination of absorption and the processes involved in the actual determination of the percent gain by weight due to absorped water. Water Repellant Cotton Oxford was available for this experiment. The test procedure required that a strip of 6 yd. of cloth be laundered at each laundering. However, only 1½ yd. are required for a complete determination. Then, since four different laboratories could be prevailed upon to join in the experiment, and since a strip of cloth 24 yd. in length was considered to be homogeneous with respect to dynamic absorption, and since two such strips could be obtained, the experiment was as follows. Each strip was cut into four 6-yd. strips. One of these was assigned at random to each of the laboratories for laundering. Then, after laundering, the 6-yd. strips of cloth were cut into four 1½ yd. strips, and one of these strips was assigned at random to each of the four laboratories for determination of dynamic absorption. Thus, we had a split-plot design. Two dynamic absorption evaluations were made on each 1½-yd. strip. The averages of these were reported by each laboratory. The yields are shown in Table VII, the analysis of variance in Table VIII and a two-way table of averages in Table IX.

Needless to say, many were surprised at the results. For, by Tukey's method for separating means into groups, the laundering averages fell into the groupings (A) (B) and (C, D) and for the testing averages the groupings are (A, D) (B) and (C). Nobody was equivalent to the standard laboratory. However, the gross deviations from the standard were traceable to assignable causes of variation and corrected.

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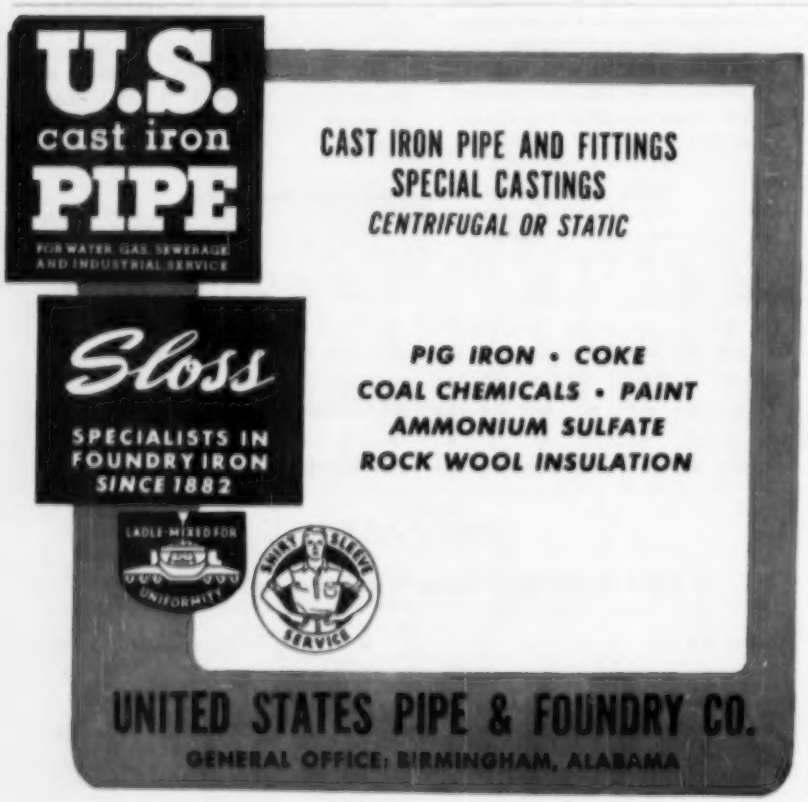

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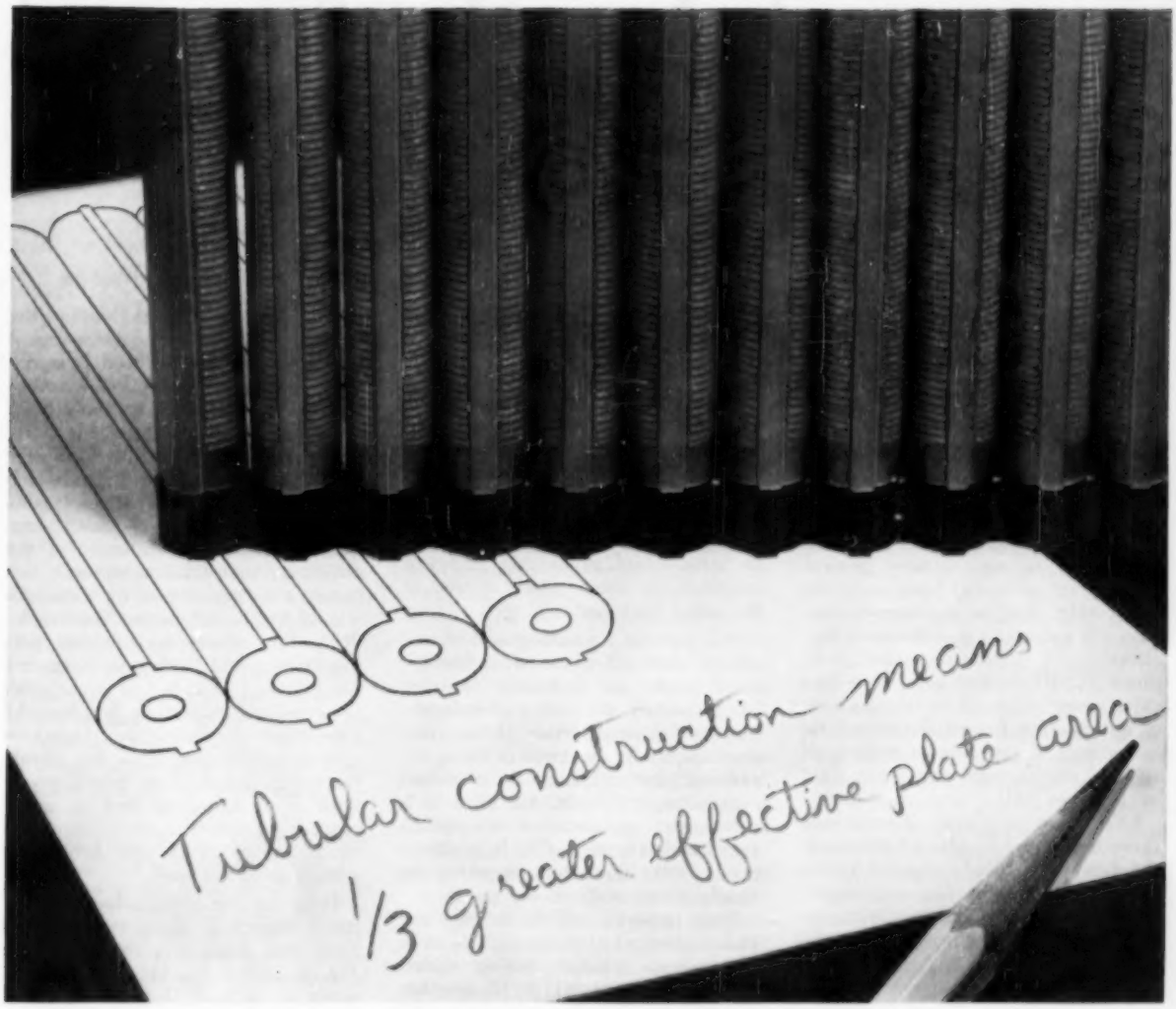

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The Use of Continuous Sampling In Ammunition Procurement

R. L. STORER

Ordnance Ammunition Command, Joliet, Ill.

Introduction

Continuous Sampling Inspection Plans are a relatively recent development in the field of inspection and quality control, but they are by no means new. The theoretical aspects of such plans have been covered by Dodge[1][2][3] and in a somewhat different form by Wald and Wolfowitz[4]. Several detailed explanations of the operation of such plans are available. Our purpose here is not retrace ground which has already been covered adequately, but to summarize experience gained in a wide-scale application of Continuous Sampling Plans (CSP) in the hope that this experience will be of use to you both in anticipating future developments in the field of government inspection and in applications for your own purposes as well.

The plans we shall discuss are those developed by Harold Dodge in the references cited, adapted to the requirements of Ordnance inspection by personnel of the Ordnance Ammunition Command, an establishment of the U. S. Army located at Joliet, Illinois.

Ammunition Procurement

The Ammunition Command functions as a sort of "home office" for the manufacture of all standard types of ammuntion used by the Armed Services. The mission is accomplished in part with production facilities owned by the government, and in part by utilizing the output of a number of vendors and suppliers.

One type of government-owned plant operates much like an automobile assembly plant. Using metal parts and explosives manufactured at other locations, these loading plants add explosive elements to each of the parts and subassemblies, as required, and assembles the elements into a finished round or item of ammunition. Other government-owned plants manufacture explosives and certain metal components which for one reason or another are not available from the production capacity normally utilized by civilian industry.

Hundreds, at times thousands, of vendors located in all parts of the United States are required to supply the loading and assembly plants. In addition, certain industrial firms have been given contracts for producing finished items which require no subsequent processing and are supplied by these plants direct to the using Services.

Our present inspection system requires that all material manufactured under an Ordnance contract be inspected prior to acceptance. Since a high proportion of the vendors are under contract to the government rather than to a prime contractor, it follows that there is a substantial government inspection organization involved in this enterprise, with inspectors working in nearly every state in the union.

The remarks which follow are based upon experience gained over a two-year period during which Continuous Sampling Inspection was progressively applied, on a trial basis, to a wide variety of inspection problems. At the present time, CSP is in use on about 165 jobs in eight loading plants and about 20 vendors' plants. The applications cover attribute inspection of clock-work fuzes, large bomb bodies, assembly of metal components for fuzes, subassemblies and assemblies of ammunition, filling shell with explosive charges, manufacture of cartridge cases, and a number of other manufacturing operations. The range is broad enough, we believe, to assure that the results are similar to those which would be experienced in the machining, metal working and assembly of metal components of a wide variety of civilian goods. The analogy would probably extend, also, to some aspects of the electronics and aircraft industries.

Typical Inspection Set-up

For economy reasons, most of the inspection done by the government in the field of ammunition procurement is source inspection—that is, inspection performed at the site of manufacture. The necessary attribute inspection is usually done in a series of stations or stages, each having associated with it a Classification of Defects (CD). Each stage is considered independently of the others so that final acceptance becomes a matter of passing a succession of inspection stages. The breakdown into stages is arranged primarily to avoid having to disassemble material in order to accomplish the required inspection, and has the side-effect of relating the inspection system rather closely to the manufacturing setup. The interdependence is so complete that in many cases the product must be inspected as it moves from one processing operation to the next.

Prior to the installation of CSP, most inspection along conveyorized lines was done in accordance with the so-called "moving lot" provisions of MIL-STD-105A. The instructions provide, among other things:

(1) that the MIL-STD sample size be pro-rated over the expected lot size; i.e., if the expected lot size is 10,000 and the indicated sample size is 300, the inspector will usually collect his sample by taking three pieces from each 100 pieces passing the inspection station;

(2) that rejected material be returned to the contractor. Disposition of such material, if it is not government-owned, is a matter for the contractor's discretion. He usually screens the material if possible; otherwise it is reworked or scraped. Government-owned material is screened or otherwise corrected;

(3) that material be allowed to pass the inspection station so long as the evidence for rejection is inconclusive.

This system led to a number of problems. The most serious of these, when it occurred, was the expense entailed in recovering rejected material. With product continuously in motion and being allowed to pass the station until proved rejectable, part or nearly all of the material involved in a lot might have passed through one or more subsequent processing operations by the time the reject number was reached. As a result, product would have to be unpacked, disassembled, removed from the production line, placed in a segregated area, or handled otherwise at considerable cost following the rejection decision. It might be thought that the expense involved in this situation is less a concern of the government than of the contractor. The presumption of such an argument is "Well, if the contractor doesn't want the expense of unloading the product from a boxcar, he should keep the quality high enough to prevent rejection." The fallacy in this attitude is twofold:

(1) Often the government owns the material and is paying the entire operating expense on a direct reimbursement basis. In other words, some of the largest contracts are of the cost-plus-fixed-fee type.

(2) Even if the material were not government-owned, the increased costs occasioned by this kind of handling still have a tendency to be reflected in the price paid by our government for the product. Renegotiation clauses, waivers, prices for additional quantities of the material, etc., all afford the contractor a means to recoup such costs if they must be temporarily absorbed by him.

Another difficulty, less serious financially but more serious quality-wise, was the practice of "cutting-off" lots when the acceptance number was reached or approached. For instance, we normally consider a lot as being a day's production passing a particular inspection station. Suppose that by 1:00 p.m. of a certain day the acceptance number is reached. If another defect is found not only will all the material produced up to that time be rejected but also (since we expected the entire day's output to comprise the lot) a large number of pieces are rejected which are not yet even made. Much of the material, as we have indicated, may already have moved into subsequent processing operations and some of it may even be packed in the boxcar.

Since the inspection lot sizes are flexible, the manufacturer in such a situation usually calls an end to that particular lot at the point where the acceptance number is reached and starts a new lot and a new sample, thereby avoiding almost certain rejection. The disadvantages of this practice are evident. We do not, under such a setup, obtain the same sort of quality as we would get if we caused the entire day's production to be rejected and returned to the contractor for screening or correction. What is worse, the absence of direct and immediate action on the part of the government to reject the material leads to an unsatisfactory attitude toward quality on the part of both the inspector and the manufacturer. On the other hand, weighing the importance of some of the defects involved against the cost of unpacking, disassembling and reinspecting every piece in the lot, one cannot conscientiously go along with the drastic action a literal interpretation of the rules would require. As a result, the "lot cut-off" practice, far from being censured, eventually gained a certain measure of respectability and in certain instances is still accepted as standard operating practice.

Another difficulty encountered with the conventional inspection system is better classified as a nuisance than as a problem. It arises from the fact that lot sizes occasionally fall on the dividing line between MIL-STD sample size classes, so the inspector is faced with the necessity of picking up 100 to 200 extra samples near the end of the day if a lot runs a few hundred over an estimate; or he is faced with a decision as to which of his samples to declare surplus in case the lot packs out a few hundred short of the estimate. Aside from its nuisance value, this situation is not conducive to a good sample. In the first case, there is an excessive density of sampling near the end of the production run, and in the other case, some parts of the run are sampled to excess while others are not sampled at all.

Some of these difficulties can be corrected by accumulating or banking the material at the inspection station. However, this is not always satisfactory and more often than not is impossible. Banking of material increases inventory cost. A fuze manufacturer, for example, told us that elimination of banks at our CSP inspection stations caused a reduction of a quarter of a million dollars in his in-process inventory. Banking also increases the time required to convert raw or semi-finished material to a finished product. Product which must be allowed to sit in a bank while nothing is being done to it is, in a sense, product withheld from the production output. In time of emergency, it can have great importance. The increase in production cost and time required by inspection banks is not offset, in many cases, by any appreciable advantages. Banking does little to lessen the attractiveness of the lot cut-off feature, for instance, unless it is accompanied by a strict application of the static lot principle.

Essentials of a Continuous Sampling Plan

Basically, a Continuous Sampling Plan of the type developed by Mr. Dodge operates in the following way. Inspection begins by screening the product 100 percent in the order in which it is produced (or as nearly so as possible), removing defects when found and replacing them with good pieces, and simultaneously keeping track of the number of pieces in each observed run of good pieces. When a run of "i" successive pieces free of the defect(s) for which inspection is being made has been observed, 100 percent inspection stops and sampling inspection begins. This period of 100 percent inspection is called the "qualification phase."

Sampling consists of inspecting one piece out of every 1/f pieces passing the inspection station. So long as this running sample contains no defects of the kind being inspected for, production is allowed to pass the station and is accepted. If a defect is found in the sample, however, 100 percent inspection is reinstated immediately and continues until the process is again qualified by a run "i" successive defect-free pieces, whereupon sampling is resumed.

The parameters "f" and "i" are predetermined, and may be selected in such a way as to provide practically any desired degree of AOQL protection.

This procedure is known as CSP-1. There are two variants of this plan which Dodge has examined, known as CSP-2 and CSP-3. CSP-2 differs from CSP-1 in that return to 100 percent inspection does not take place immediately upon the finding of a single defect in the sampling phase, but only when the first defect is followed by another in less

than "k" inspected units. CSP-3, in turn, is similar to CSP-2, except that the inspector examines the four units immediately following the first defect in the sampling phase. Depending on whether or not another defect is found among these four units, he reverts to 100 percent inspection or starts keeping count to determine if a defect occurs within "k" inspected units.

OAC Manual of Continuous Sampling Plans

The Manual of Continuous Sampling Plans which is used on Ordnance Ammunition Command contracts was developed over a period of about 18 months from the experience previously mentioned. We started with a simple plan on one kind of operation, and as the diversity of applications grew, the character of our sampling plans also changed and eventually resulted in the series of plans reproduced here as Tables I and II.

These tables utilize values of f which require sampling frequencies ranging from one piece out of each 200 to eight pieces out of each 100 passing the inspection station. The qualifying periods vary accordingly, ranging from 12 pieces to over 3,000 and the associated AOQL's range from 0.12 percent to 10.7 percent. It should be noted that AQL is used only as a label, in our practice, and does not imply that the characteristic curve passes through any particular point. In the two tables we are discussing, the AQL is included primarily as an index to the MIL-STD-105A plan which would yield about the same AOQL as the CSP plan if it were used on an AOQL basis. In most instances, the conventional inspection system actually does have AOQL connotations, for the customary action taken by the contractor upon the return of a rejected lot is to screen the lot under the supervision of an Ordnance inspector, removing all defects of the kind causing rejection.

In addition to the wide range of i, f and AOQL values, plans developed at OAC also provide for the use of either CSP-1 or CSP-2. Each feature of the plans we now have is the result of a problem or situation in the field which required an expansion, addition or change to the simple plan with which we started in 1952. We therefore expect that the set of plans will have wide and successful use in the future.

Effect of CSP on Quality Consciousness

Initially, we investigated the use of CSP in the hope of eliminating the expensive recall provisions attendant upon the conventional inspection system and concurrently of reducing the amount of material which had to be banked near inspection stations. When these banks consist of explosives, they become safety hazards as well as production and fiscal problems. There is no question but that the CSP plans either eliminate or materially reduce troubles of this sort.

The most important benefit, however, was unexpected. Under the conventional inspection plan, rejection did not follow until sometime after the finding of the first defect. The MIL-STD-105A plans most often used have rejection numbers as large as 15. Several hours' production is ordinarily required to generate enough defects to cause rejection. In view of the "lot cut-off" feature discussed earlier, rejection may not follow a run of quality trouble, except under very difficult circumstances. By contrast, CSP-1 causes immediate rejection of the process and use of screening as an expedient means of quality correction upon finding of the first defect. CSP-2 is a little weaker in this respect, delaying corrective action until a second defect is found too close on the heels of the first. In either case, however, action is sufficiently direct, and the severity of the consequences is such, that the need for attention to quality becomes quite evident at all levels from operator to production superintendent. Inspectors and production supervisors have both remarked on the increase in quality consciousness as an outstanding by-product of CSP. These comments, be it noted, are not isolated but have arisen independently from nearly all users of the plans.

Concern was at first expressed that CSP tended to venture into the field of process control and might come to be used as a replacement for controls which the manufacturer ought to maintain himself. So far, the observed effect has been the opposite. Following the introduction of Continuous Sampling Plans, quality control programs have sprung up and prospered in plants where there had been literally no process control system before. It is our opinion that this is a natural consequence of the use of CSP. Any attempt to rely on the government's use of CSP, alone, as a means of controlling outgoing quality is almost sure to fail if the quality is uniformly bad or very erratic. The reason is that a constant load of 100 percent inspection for all defects is a possible, and in some cases even a probable sequel to poor quality. Worse yet, there may be a rapid alternation between periods of 100 percent inspection and sampling inspection. The manufacturer has to supply the manpower necessary for 100 percent inspection phases, and the 100 percent inspection itself

TABLE I—Values of i for CSP-1 Plans by f, AQL and AOQL

AQL	f Values 0.005	0.01	0.02	0.04	0.08	AOQL
0.015	2630	2210	1780	1380	1030	0.12
0.035	1970	1660	1340	1040	770	0.16
0.065	1370	1150	940	730	540	0.23
0.10	1170	980	800	620	460	0.27
0.15	880	740	600	470	350	0.36
0.25	530	450	370	290	210	0.59
0.40	380	320	260	210	150	0.83
0.65	300	250	200	160	120	1.08
1.00	240	200	160	130	100	1.35
1.50	150	120	100	75	60	2.20
2.50	100	85	70	55	40	3.09
4.00	65	55	42	34	25	4.96
6.50	43	36	29	22	16	7.24
10.00	28	24	19	15	12	10.70

TABLE II—Values of i and k for CSP-2 Plans by f, AQL and AOQL*

AQL	f Values 0.005	0.01	0.02	0.04	0.08	AOQL
0.015	3200	2650	2200	1750	1350	0.12
0.035	2400	2000	1650	1320	1000	0.16
0.065	1660	1380	1150	920	710	0.23
0.10	1410	1180	980	780	600	0.27
0.15	1060	880	730	590	450	0.36
0.25	640	540	450	370	280	0.59
0.40	460	380	320	260	200	0.83
0.65	360	290	250	200	160	1.08
1.00	290	230	200	160	130	1.35
1.50	180	150	120	95	75	2.20
2.50	130	110	85	65	55	3.09
4.00	75	65	55	42	32	4.96
6.50	55	42	35	28	22	7.24
10.00	33	27	23	19	14	10.70

*k is equal to i.

tends to slow down the rate of production on the line. Hence if the absence of adequate process controls led to a deterioration of quality, the manufacturer would soon be apprised of the situation in terms which are very real to him—namely increased labor costs and lowered production rate. One or two experiences of this kind are enough to convince him that preventive measures are in order.

Sampling Frequency

Determination of the f-value to use in a given situation is a matter we have been unable to reduce to a simple formula. On one hand, the relative amount of inspection should be kept as small as possible to minimize costs, which means that f should be small. On the other hand, if f is too small, short segments of bad quality may be overlooked because they are not sampled.

A natural first solution to this problem is to specify a larger f for the important defects than for the unimportant defects. In our first plan, for example, we provided a four percent frequency for Critical defects and a two percent frequency for Major defects. We found, however, that this practice creates a difficult situation if both kinds of defects are inspected for at any given station. It requires that the inspector take four from each 100 pieces produced as a sample for Critical defects and of these four that he choose two to be examined for Major defects. Suppose that while inspecting for Criticals, or while in the process of drawing the sample, he discovers a Major on one piece. Should he then call that piece a part of the Major sample or not? Or worse, suppose he does not notice the Major until he has picked two of the other three samples as representing a sample for Major defects and has found these two to be free of Major defects. In view of the potential for differences of opinion in such situations, we have adopted the practice of using a single value of f for all defects at a station.

Some of the methods we have used in determining f are as follows. It should not be inferred that these constitute a complete set of rules. These statements are merely considerations which we have followed with reasonably good results so far.

(1) If the material is simultaneously processed in batches, we use a value of f which will provide a sample of at least one piece from each batch.

(2) If the inspection station is concerned with an assembly operation or a relatively stable and simple series of machine operations, we usually use $f = 0.01$ provided that the production rate can be expected to fall somewhere in the range of 5,000 to 20,000 pieces per day.

(3) If the production rate is very low, say less than 500 pieces per day, we usually use $f = 0.08$.

(4) If the production rate is extremely high, say 50,000 per day or more, an f of 0.005 is indicated in most cases.

(5) For situations intermediate to those previously named, we select a frequency which seems to balance the factors of minimum amount of inspection, reasonable amount of information, and adequate protection against spotty quality. While it has, on occasion, been advisable to consider each manufacturer as a separate problem in determining the value of f, we have found that the sampling frequency can more often be specified by item or by the type or nature of the operation. For example, shell filling is, for the most part, a batch process, the batches being either 25, 36, 54 or 80 pieces, depending upon the size of the shell. Hence we specify four percent for 25-36 shell batches, two percent for 54-shell batches and one percent for 84-shell batches, or one percent in the case of continuous pouring in lieu of batch processing. Large bombs are usually produced at a very slow rate and an eight percent value of f therefore fits most bomb manufacturing operations. Almost all conveyorized assembly operations may be satisfactorily handled by a frequency of one percent. As a result of "cut and try" methods of this kind, we should eventually be able to provide fairly simple rules for inspection procedure writers to follow in selecting the value of f to be specified. If, in the meantime, someone is able to present a straightforward method for selecting the optimum value of f, we shall all be much better off.

Amount of Inspection

Table III summarizes experience with the conventional and CSP plans on a shell-filling inspection at nine plants over a period of several months. The notations "CSP" and "105A" in the right-hand column of the table refer to continuous sampling plans and moving-lot inspection by MIL-STD-105A, respec-

TABLE III—Summary of Inspection Results

Facility	No. of Lots Presented	Total No. of Units Presented (Thousands)	Avg. Sampling Insp. Frequency (%)	Process Average, %		100% Inspection (% of Total Presented)	Sampling Scheme
				Critical	Major		
Iowa Ord. Plt.	56	3,591	3.68	0.000	0.020	0.22	CSP
	295	5,400	5.48	0.004	0.187	2.03	105A
Joliet Arsenal	355	5,245	4.87	0.001	0.009	0.04	105A
Kansas Ord. Plt.	443	5,117	3.23	0.001	0.074	1.35	CSP
	127	1,222	3.71	0.000	0.066	0.33	105A
Kingsbury Ord. Plt.	17	78	3.29	0.000	0.000	0.00	CSP
	220	825	5.19	0.000	0.070	3.61	105A
Lone Star Ord. Plt.	82	1,843	3.31	0.026	0.310	3.87	CSP
	341	8,897	3.26	0.004	0.061	0.86	105A
Louisiana Ord. Plt.	249	2,974	3.54	0.001	0.009	0.19	CSP
	355	5,819	3.55	0.002	0.063	2.12	105A
Milan Arsenal	50	1,000	4.48	0.002	0.011	1.42	105A
Nebraska Ord. Plt.	176	5,248	1.77	0.019	0.050	1.29	CSP
Ravenna Arsenal	254	3,073	4.91	0.001	0.247	3.16	CSP
	136	1,130	6.73	0.085	0.291	1.70	105A
Totals	1277	21,924	3.24	0.007	0.108	1.45	CSP
	1879	26,538	4.37	0.008	0.096	1.33	105A

TABLE IV—Outgoing Quality Obtained by Use of CSP in a Situation of Poor Quality

Quantity Mfg'd	% Inspected by Sample	Total % Inspected During Production	% Defective at Time of Presentation	% Defective of Accepted Material	AOQL in %
34,381	1.82	30.97	Cr. 0.84 Ma. 0.38	Cr. 0.08 Ma. 0.19	Cr. 0.12 Ma. 1.09

tively. Most of the CSP inspection involved was done under plans designed to approximately equal the conventional plan in relative amount of material inspected on a sampling basis. Even so, it is evident that the use of CSP caused an important reduction in work load at some plants. On the other hand, it caused notable increases in screening in others. Considering the overall picture, the total amount of sample inspection remained approximately the same on CSP as under the conventional plan. Obviously, this circumstance arises because the CSP plan was so designed. It is equally clear that CSP could be made to show either a reduction or an increase in the relative amount of material inspected on a sampling basis depending upon the relation between f and the corresponding fraction m/M of a MIL-STD plan.

Apparently, substantial reductions of the total amount of inspection required under the conventional plan can be made without much, if any, sacrifice in outgoing quality. For instance, we recently investigated the outgoing quality in a very difficult situation. The operation involved, known as melt-pouring, is sometimes tricky to control. Quality can change abruptly without anyone knowing very precisely when or why the change occurred. A shell-filling job developed serious quality trouble twice during the filling of about 35,000 shells. A two percent CSP plan was in use at the time this difficulty arose. The effect of the CSP plan on the outgoing quality can be judged from the data of Table IV which was reconstructed from inspection results during the manufacture of the material and by inspecting all material passed by the inspector.

The 31 percent total of product inspected during the production is a reflection of the extent and duration of trouble encountered and will, of course, vary with the frequency with which the defects occur. Thus, at the expense of sampling less than two percent of the product (as opposed to more than three percent under the conventional plan) and of detailing 30 percent of the output, the fraction defective of Criticals was detected and reduced from 0.84 percent to 0.08 percent in the accepted material. This is about the same result as would be obtained under the conventional MIL-STD-105A approach by 100 percent reinspection at 90 percent efficiency. The cost of doing the job by CSP is estimated in this case to have been about ten percent of the cost by conventional means.

Application of CSP

CSP seems to appeal intuitively to inspector and producer alike, so training in the use of the technique is not difficult. After the first pilot application, we called all District and Plant inspection administrators together for a training session in which we discussed the basic ideas of the plans rather thoroughly. These administrators, in turn, have made it a practice to discuss CSP very thoroughly, both pro and con, with the producer. In talks with the producer, the intimate relationship between quality, rate of production and cost is stressed. Special pains are taken to insure that the producer fully understands that a sequence of defects will reduce his rate of output to that of the screening crew, and that the screening must be done properly. This approach has been very effective in creating a team spirit with respect to CSP, has assured thorough and considered trial, and has minimized the confusion which always accompanies a change in method.

It is sometimes said by persons considering its use that CSP should not be used except where the quality history is good. Normally, we make the same recommendation, but for a very different reason. The person to whom CSP is new is likely to want to try it only on stable high-quality operations because, he says, he is not satisfied that it gives him "equal assurance." One who has used it is not likely to be worried about the "assurance" (whatever that may be) but is worried at the effect on the production rate if CSP is applied on an erratic or poorly controlled line.

Inspection stations set up for the conventional plan and for inspection on the basis of the defective may need to be re-organized under CSP. Defect lists may be too long for rapid inspection. Or, some disassembly may be necessary under the conventional plan. Usually, we find, the inspection can be done with minimum manpower and maximum effectiveness by locating the necessary inspection as close as possible to the place where the defect originates. This practice leads to some troubles of AQL readjustment and similarity of inspection reporting if the defective continues to be the basis of judgment. Accordingly, we usually provide for judgment by *defect* under CSP. This is simple and straightforward, eliminates one bookkeeping operation, prevents such difficulties as having to clean up all Minors because of the occurrence of one kind of Minor in a sample, and greatly simplifies the screening operations.

Several contractors have commented that relations between the government inspector and the contractor have improved noticeably following the introduction of CSP. They say there is much less friction; that the inspector's decisions, while no more popular than before in case of a rejection, seem to be more soundly based and more readily accepted. It is possible that the inspector may be more keenly aware of his responsibiltity, in view of the drastic effect his decision may have. It is also possible that the contractor, freed from the worry of a rejection under the difficult situation of having to recall and reinspect product, takes a more charitable view of government inspectors. Whatever the reason, this mutual increase in respect has been most heart warming.

Scope of Future Applications

CSP is, I think, going to play an increasingly important part in the design of inspection plans and systems because it is consistent with a sound fundamental of inspection planning. Specifically, an inspection plan, including especially its sampling phases, will be useful and efficient in direct proportion as it is designed to fit the needs and limitations of a particular production and inspection situation. MIL-STD-105A is so designed that it works best when the material to be inspected is a finished and static mass, from which samples may be drawn and inspected, with decision following upon completion of inspection of the entire sample. For Receiving Inspection or any other attribute inspection of static material, it is difficult to equal.

Conversely, it should occasion little surprise that the same Standard

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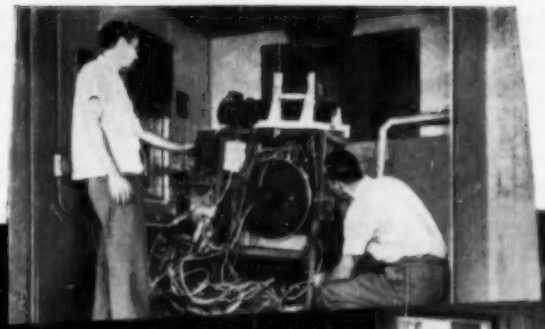

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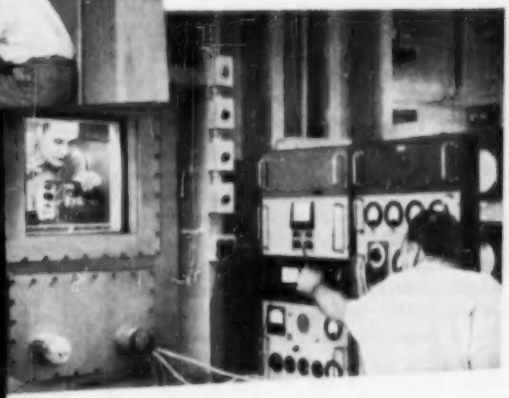
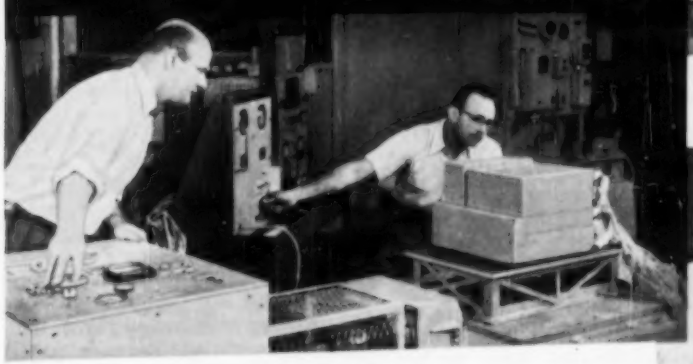
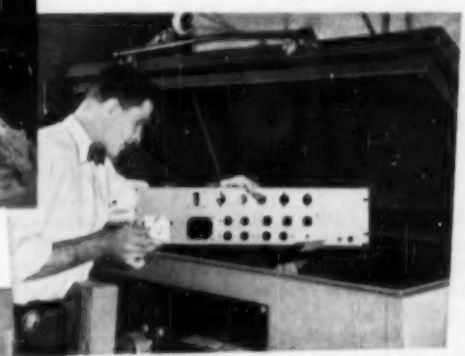


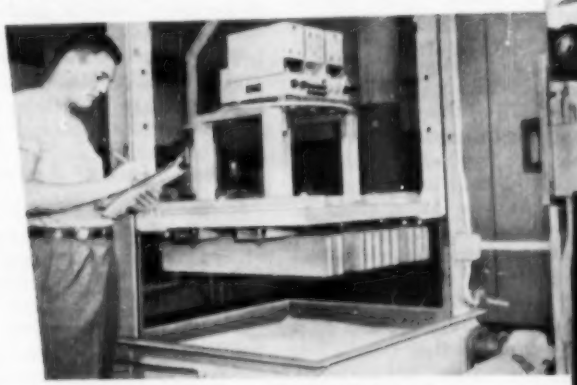
Altitude Test Chamber simulates atmospheric pressures and temperatures to prove superior performance of Du Mont equipment for high altitude flying.



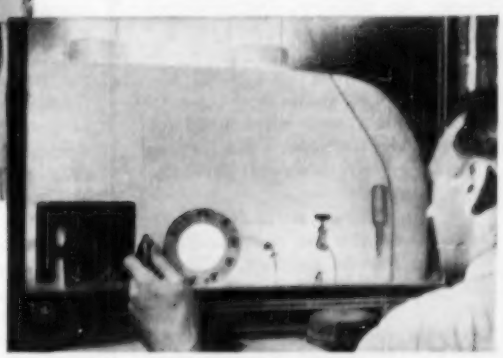
Here, Du Mont equipment undergoes vibration tests to guarantee its operation under extreme conditions.



Sea-borne Du Mont electronic gear also receives exhaustive tests like this salt spray which establishes the fact that Du Mont equipment will perform under such extremes of exposure.



Grueling Drop-Shock tests prove that Du Mont equipment will continue to operate under extreme stresses and strains.



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leaves something to be desired when applied in a climate of multi-stage inspection, moving product, and what amounts to decision piece-by-piece. Nor is it very remarkable that the Dodge Continuous Sampling Inspection Plans, designed for just such a situation, should fill the need more effectively and efficiently.

The probability of successfully combining the ideas in NAVORD-OSTD-81 with those in the OAC Manual to form a standard for attribute inspection of moving product suitable for wide application in the Department of Defense is, I think, very good. Standardization is feasible if it be kept in mind that many people will require the plans for many situations; that therefore standardization cannot be synonymous with rigidity of procedure; that a good standard must really be somewhat like a set of Standard Gage Blocks—a set of known elements from which each planner can fashion a setup to suit his particular needs.

I believe, also, that CSP has great potential in industrial usage as a final inspection device and as a control on assembly or other manual operations where quality is largely a function of the individual's attention to his work.

Summary

If it had done nothing else, this experience with CSP would have been worthwhile because it probably means the end, or the beginning of the end, of an era of thinking in terms of an all-purpose set of Sampling Tables. The advantages to be gained by accommodating the inspection to the production situation, rather than vice versa, are obvious. In addition, the evidence seems pretty compelling toward the following conclusions:

(1) Properly applied, CSP encourages the growth of quality consciousness and, when used for acceptance purposes, encourages the use of effective control during processing.

(2) As a replacement for a plan based upon the use of MIL-STD-105A on moving product, CSP has saved and will save substantial sums of money by eliminating the need for recalling material which has already passed the inspection station and by forcing corrective action on product yet to be made.

(3) CSP has demonstrated that under certain circumstances it is not necessary to inspect large fractions of the output, as compelled by the smaller lot sizes of MIL-STD-105A; on the other hand, it has cast some doubt upon the wisdom of a casual use of the very large lot sizes of MIL-STD-105A, particularly under reduced sampling.

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(3) Dodge, Harold F. and Torrey, Mary N., "Additional Continuous Sampling Plans," *Industrial Quality Control*, VII, No. 5, 1951, pp. 7-12

(4) Wald, A. and Wolfowitz, J., "Sampling Inspection Plans for Continuous Production Which Insure a Prescribed Limit on Outgoing Quality," *Annals of Mathematical Statistics*, XVI, 1945, pp 30-49

Correlation Analysis in Batch Process Control

JOHN D. HINCHEN

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Introduction

In order for a finished product to have consistent high quality, the desirable characteristics have to be "built in" all along the line. Statistical quality control exists, and is successful, mainly because it assists the manufacturer in performing the very vital task of making the quality right the first time through. However, much of the literature on the use of statistical methods in product quality control has been devoted to development of the techniques for separating the two basic types of variation—that which is inherent to the process, and that which is indicative of new or changing causes of quality variation. The main advantage of these techniques is that they tell the production man when an "assignable cause" of variation exists in the process. The task of locating and correcting this cause is not necessarily assisted by the ordinary quality control methods.

In many chemical processes, this type of control is usually an "after the fact" proposition—the basic control of quality must be handled while the product is being manufactured. The people responsible for the control of finished quality find that their chief responsibility lies in guiding the course of the reaction so that the desired end goal is reached in each batch of material.

Many statistical techniques are available and can be of use to the manufacturer for establishing the required control of operating conditions, and pinpointing the critical turning points in the reaction. One of the most valuable of these methods is correlation analysis, and we hope to show by example how this useful statistical technique can help to establish more critical control of process performance.

Background of the Problem

In the manufacture of a certain type of synthetic liquid resin, some of the properties of importance are the mineral spirits tolerance and the solids content. For some end uses, too little mineral spirits tolerance precludes the use of the material in the optimum concentrations required by the customer; too great tolerance indicates a low molecular weight product which may have processing characteristics that are in many ways undesirable. Solids content control is important to both the manufacturer and the user. A uniform resin concentration helps both of these people maintain predictable cost control, and provides uniform handling properties.

The reaction process for the resin under consideration consists of two phases. In the first phase, the monomer is reacted to a certain stage.

This controls, among other things, the mineral spirits tolerance of the finished product. The second stage of the reaction consists of the removal of the water present. The amount of water removed will control the solids content of the end product.

The process as originally developed was established to produce a resin which varied somewhat widely in dilution characteristics. As we became more skilled in evaluating the material, we began to find that certain batches of resin enabled us to use optimum operating conditions, resulting in a better yield and reduced operating cost. Working together with the end user, it was determined that resin having tolerance values of between ten and 20 was the most desirable. These limits were established as tentative manufacturing specifications. It became the problem then to control the initial portion of the cycle very closely, so that the finished product would fall within the required limits.

The progress of the initial portion of the cycle was followed by testing the amount of monomer remaining unreacted in the reaction mixture. The amount of unreacted monomer became gradually less as the reaction proceeded, and with reagent and catalyst concentrations fairly well controlled, had a fairly good relationship with the average molecular weight of the finished product. In order to determine the control point at which the reaction would be quenched, it was necessary to study process history to determine the monomer content at changeover (end of reaction cycle) for those batches of resin which had the desired final properties.

Control of Reaction Step

Table I shows the monomer content at changeover, and the final tolerance of twenty lots of resin. By plotting these values on a scatter diagram it was found that the relationship between the two properties was curvilinear (See Fig. 1.) Since the tolerance was expressed as a ratio (volumes of naphtha to volumes of resin to produce precipitation,) it was felt that some advantage would be gained by plotting the variable on a ratio or logarithmic scale. Figure 2 shows that the relationship thus obtained appears to be linear. To verify this conclusion, and to establish the relationship between free monomer at changeover and final tolerance, the data were analyzed by simple linear correlation, using the logarithm of the tolerance as the dependent variable.

Table I

Percent Monomer at Change-over	Mineral Spirits Tolerance	Log. M. S. T.
1.0	5.0	0.70
1.2	4.9	0.69
1.6	5.0	0.70
1.9	7.0	0.84
2.0	10.2	1.01
2.1	9.5	0.98
2.4	10.5	1.02
2.5	8.5	0.93
2.9	11.0	1.04
2.8	14.5	1.16
3.1	15.0	1.18
3.2	19.0	1.28
3.4	14.0	1.15
3.4	18.2	1.26
3.8	16.3	1.21
3.9	18.0	1.25
3.9	21.0	1.32
3.9	26.0	1.41
4.4	29.0	1.46
4.4	24.0	1.38

The correlation coefficient as calculated from the data in Table I was 0.96, showing the relationship between the logarithm of the tolerance, and the free monomer at changeover to be significant at 99.9 percent confidence level. The least squares line representing the relationship was found to be

$$y = 0.45 + 0.22x$$

where y = log tolerance (volume of naphtha per volume of resin)

x = monomer at changeover (percent).

The 95 percent confidence limits around the correlation line were ± 0.14 on the log scale, and the line and limits are shown together with the plotted data on Fig. 2.

In order to produce a material having the greatest likelihood of meeting the tolerance specifications, it would be desirable to change over at a free monomer concentration which would correspond to the center of the tolerance range. This can be done either directly from Fig. 2, or by substituting in the foregoing equation the desired value of y and solving for x.

Hence

$$y = 0.45 + 0.22x$$

may be read as log tolerance

= 0.45 + 0.22 (percent monomer at change-over)

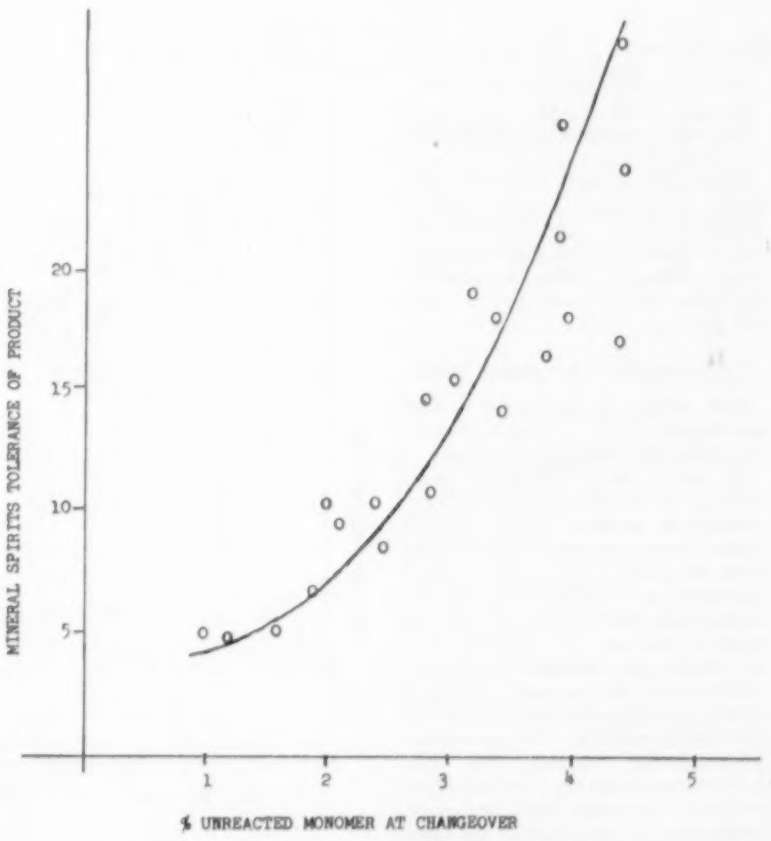


Figure 1—Untransformed Relation Between Mineral Spirits Tolerance and Unreacted Monomer at Changeover

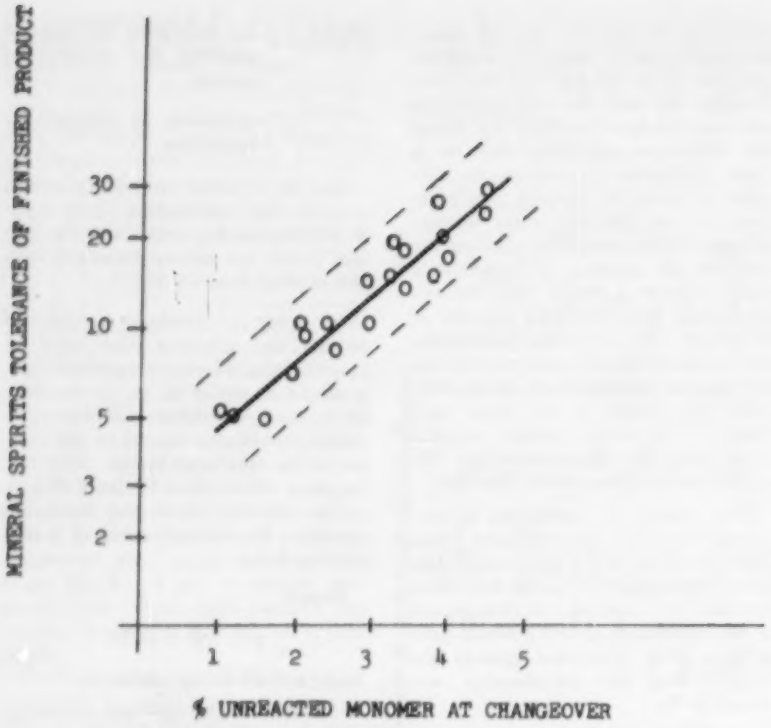


Figure 2—Line for Estimating Mineral Spirits Tolerance From Unreacted Monomer at Changeover (Log Transformation Used)

Since the log of 15 is 1.176 we have:

0.22 (percent monomer at changeover) = 1.176 − 0.45

Percent monomer at changeover = 3.3%

This is the percent monomer most likely to produce a final mineral spirits tolerance of 15. The next step was to make the required changes in procedure to enable the production department to use the new control point.

Predicting the Changeover Point

Due to the residual error around the regression line, it was necessary to make the changeover during a very narrow range of free monomer in order to obtain the greatest percentage of material within the required specifications. Up to this time, the procedure had been to plot the monomer content versus the reaction time, and to predict from the slope of the line, the probable time at which the desired changeover point would be reached. Figure 3 shows the plotted values for twenty batches of material. To avoid complicating the diagram, the lines joining the points for each batch are omitted. Although there are some differences in the slopes of the lines, the greatest difference is in the levels of monomer contents at a given reaction time. These differences are caused by partial reaction taking place during the time the batches were being heated up to reaction temperature. The differences in slope are caused by normal variations in temperature, catalyst concentration, monomer purity, etc.

This method of predicting the end-point was not entirely satisfactory. To obtain acceptable accuracy of prediction, a fairly large number of samples had to be obtained, and the dangers of extrapolation were always present. It was the production supervisor who pointed out the answer to the problem. He reasoned that we were not particularly interested in the history of the reaction up to the point of test, but primarily in how much further the reaction still had to proceed before the desired monomer concentration was reached. In other words, the variable to be predicted was not free monomer at a given reaction time, but the amount of time remaining in the reaction period, to be predicted from the measured free monomer content. The correlation analysis should be made between free monomer and "minutes to changeover," as this variable was named. However, as pointed out by

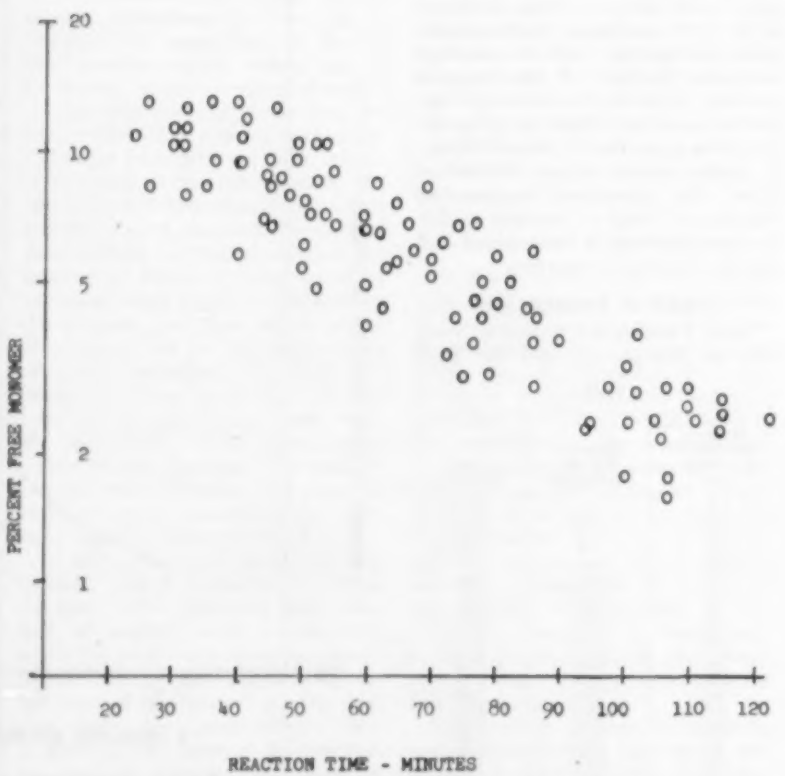


Figure 3—Free Monomer Content vs. Reaction Time

Windsor ("Which Regression?" *Biometrics Bulletin*, Vol. 2, 1946), the time factor is still the independent variable, even though it is the variable which is being predicted. We must use the line for predicting monomer content from time, in order to obtain our best estimate of the time remaining in the reaction. Using the same data as in Fig. 3, but substituting minutes to changeover for reaction time, the relationship shown on the scatter diagram in Fig. 4 was obtained.

In analyzing the available data from these 20 batches of resin, it was found that the relationship between free monomer and reaction time was not linear, but followed a logarithmic curve. The rate of polymerization was evidently proportional to the amount of the monomer remaining free in the reaction mixture. Before running the correlation analysis, the monomer values were converted to logarithms, making the principles of simple linear correlation applicable.

The correlation analyses were run using all of the available data, and both relationships were found to be highly significant. The residual error around the correlation line, was much smaller for the relationship

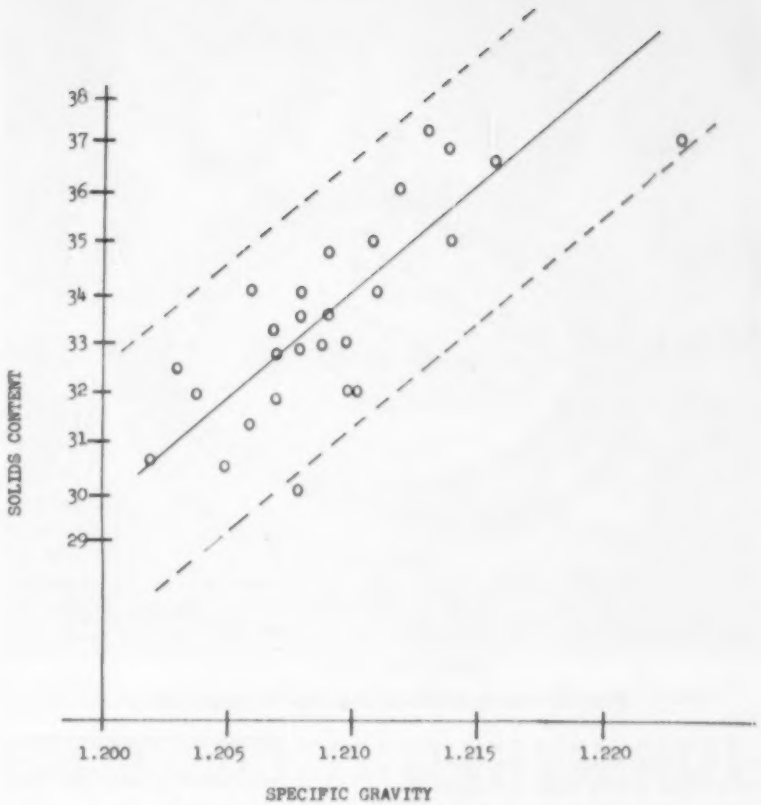


Figure 5—Line for Estimating Solids Content From Specific Gravity

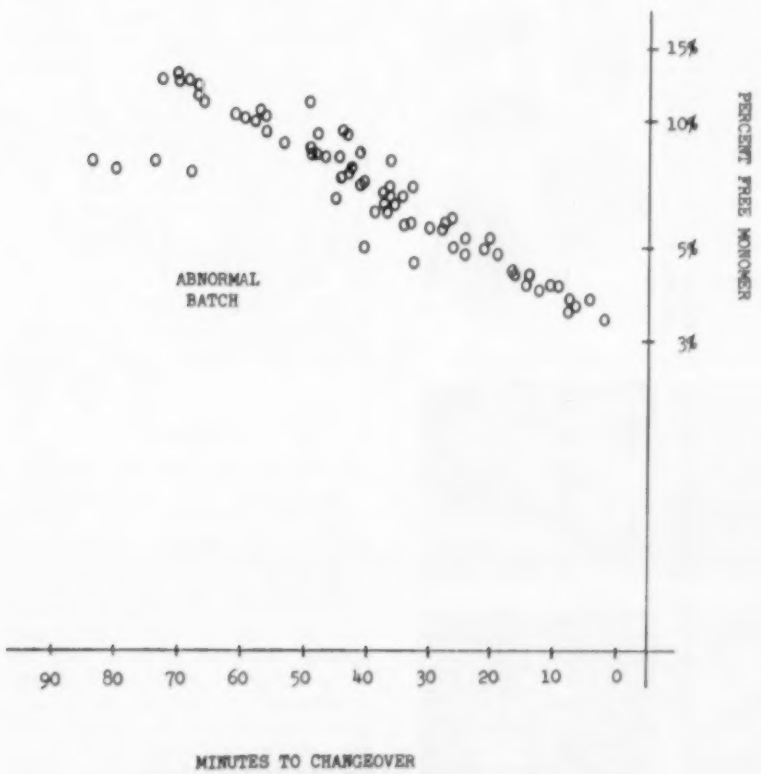


Figure 4—Free Monomer Content vs. Minutes to Changeover

which used minutes to changeover as the X variable in place of reaction time. When these data were plotted, it was found that one batch of material gave results which were consistently outside the 95 percent confidence limits around the line. On investigating the history of this batch it was found that a non-normal situation involving poor heat transfer existed, and that the rate of reaction was much slower than would normally be expected. The data from this batch were set aside and the correlations recalculated using the remaining data. The results were as shown in Table II.

Figures 3 and 4 show the two relationships plotted on semi-logarithmic graph paper. The scale is reversed on the "minutes to changeover" graph to facilitate comparison,

Table II

	Log Monomer Vs. Reaction Time	Log Monomer Vs. Minutes to Changeover
Correlation coefficient	0.80	0.98
Significance	99.9%	99.9%
Least Squares line	$y = 1.263 - 0.0073X_1$	$y = 0.518 + 0.0086X_2$
95% limits of prediction	± 0.198	± 0.066

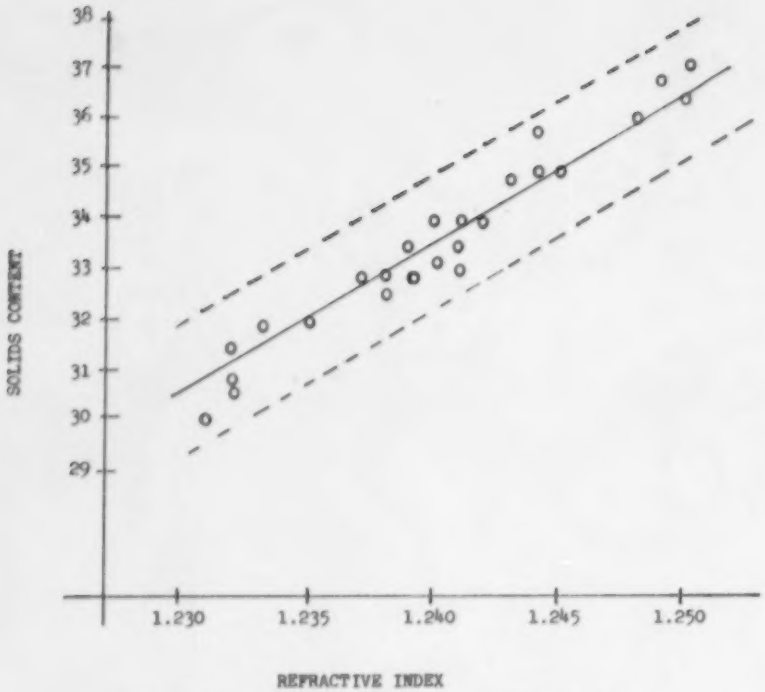


Figure 6—Line for Estimating Solids From Refractive Index

and to make usage of the chart in the normal left to right direction.

The much greater precision of the relationship between free monomer (logarithms) and minutes to changeover, led to the adoption of this method for predicting the changeover point. Forms based on semi-logarithmic graph paper were made up with the standard reaction line, and made a part of the process logs. As each sample was taken from the kettle, and the results obtained and plotted, the probable remaining reaction time was estimated. Depending on the length of this estimated time, the decision as to sampling frequency was obtained. It was possible after a period of time, to reduce considerably the number of samples required to obtain accurate changeover control. The procedure has since been extended to other resins, and has materially improved the right first time record.

Control of Dehydration Step

The customer is also vitally interested in accurate control of the solids content of the finished product. This property is controlled during the second portion of the cycle, in which water is removed from the kettle by vacuum dehydration. When the material was originally formulated, the tentative process included estimation of solids content during the course of the reaction by running a specific gravity measurement on the resin solution. Figure 5 shows the relationship that existed between the solids content and the specific gravity of several finished batches of resin.

It was decided that the relationship between these two properties was not sufficiently precise (although highly significant,) to enable estimation of solids content with the required degree of accuracy. Normal practice was to chart the progress of the reaction by specific gravity until the estimated solids content had been reached. Then the dehydration was stopped, and a sample taken for a three hour solids test. If the result was within specifications the resin was packed out; if not, further dehydration or water addition was made for solids adjustment.

In many cases, the specific gravity was affected by factors other than solids, and waiting for the solids test for three hours was often justified. However, this was costing money and processing time, so a new test for predicting solids more accurately was needed. In addition, a more precise test for solids content was developed and used as a standard

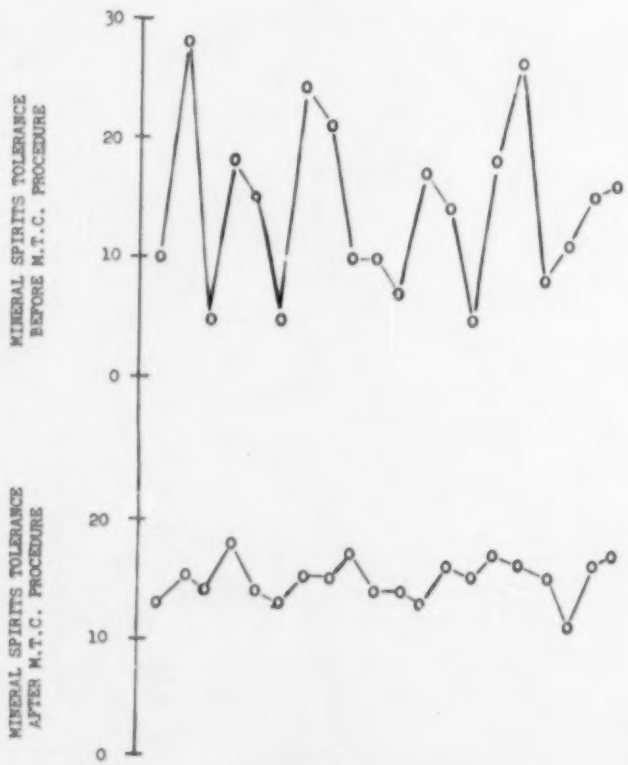


Figure 7—Effect of Minutes to Changeover Control on Mineral Spirits Tolerance

test for this product. The lab came up with the suggestion that refractive index be tried, and Fig. 6 shows the resultant relationship.

When the relationships were plotted on square-ruled graph paper it was evident that linear correlation techniques would apply without transformation. The correlation coefficients were calculated, and the following results were obtained:

1. For the solids vs. specific gravity analysis, r = 0.75
2. For the solids vs. refractive index analysis, r = 0.94.

The first relationship explains 56 percent of the total variance of the solids content, leaving a residual variance of 44 percent unexplained. The second relationship is considerably better, leaving only 11 percent as unexplained residual variance.

The two correlation lines were as follows:

1. For the solids vs. specific gravity analysis.
   % solids = 421 (specific gravity) − 475.5
   95% limits ± 2.7%
2. For the solids vs. refractive index analysis
   % solids = 305.6 (refractive index) − 345.4
   95% limits ± 1.3%

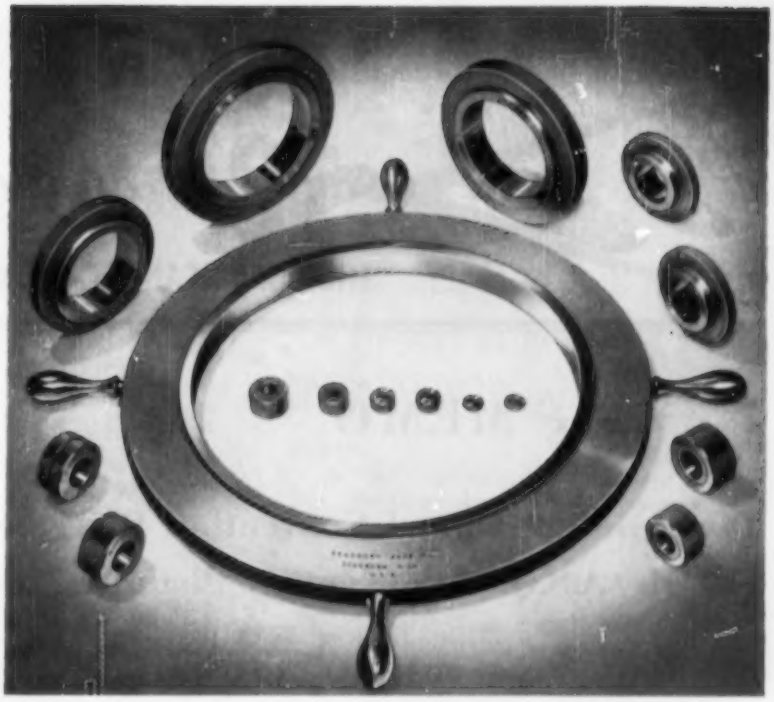
Due to the increased confidence in the predictability of the solids content, two things were accomplished:

1. It was possible to pinpoint the end of the dehydration cycle more accurately, and produce a material with a more uniform solids content.
2. The greater accuracy made it possible to drain the batch on the basis of refractive index alone, without waiting for the time-consuming solids test.

By the use of the correlation techniques, better quality and lower costs were achieved.

Conclusion

Finally, the test data on the finished product after the new procedures were installed, were compared to the previous product level and variability. The control charts for dilutability and solids content before and after the change showed clearly the effect of this approach on the finished product quality. Further application was made to other products, and the department was placed on a sounder basis quality-and-cost-wise, with the added advantage of increased customer confidence and satisfaction.



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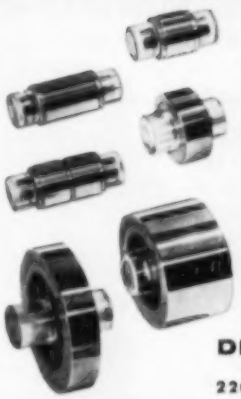

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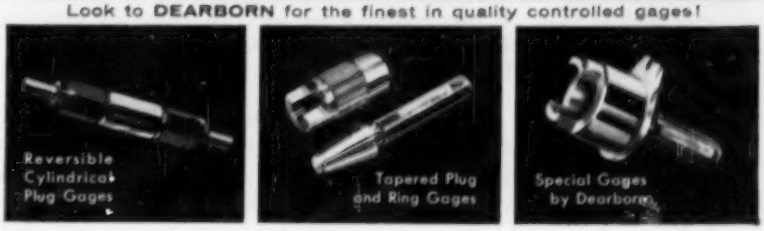

10th annual convention of
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• • • • • MEMO

TO: 10th Annual Convention Delegates

FROM: A.S.Q.C. Convention Planning Committee

LAST MINUTE REMINDERS

By now you have probably completed your arrangements to attend our 10th Annual Convention in Montreal, June 6, 7, 8. However, in planning your trip to our city there are many small details that must not be overlooked. Carefully check over the reminders we have listed below. Proper consideration to these matters will eliminate any avoidable delays and mishaps that could occur, thus making your trip to Montreal an enjoyable and memorable occasion.

Have you made your Hotel Reservations yet?

Remember that if you want to be assured of a hotel reservation, your application must be received at the office of the Montreal Tourist and Convention Bureau, 1455 Peel Street, Montreal 2, not later than May 18. All reservations mailed so as to arrive after that date should be mailed directly to the hotel of your choice. In such case, there can be no guarantee of reservations.

Will you be arriving in Montreal after 6 pm?

Confirmed reservations will be held by the hotel only until 6 pm of the arrival date unless *you* specify a later arrival time.

Have you obtained your necessary Border Crossing Credentials?

May we remind our U.S. visitors to read carefully the Customs information we have printed in the official brochure. If you follow these instructions there will be absolutely no difficulty in entering or leaving Canada.

Obtain Canadian money from your local bank

The rate of exchange fluctuates in a range of a few cents and we recommend that U.S. visitors change their U. S. currency at their local bank.

Plan to spend your vacation in Quebec

We have arranged for the Tourist Branch of the Quebec Provincial Publicity Bureau to handle any questions you may have concerning vacation spots in Canada. If you have any problems drop them a line at 1013 Dominion Square, Montreal. In addition, the Tourist Bureau will have a booth set up in the exhibits area at the Convention to handle any inquiries you may have at Convention time.

Additional copies of the official program

If you require additional copies of the official program brochure, these may be obtained from local section secretaries of the Society.

Bon Voyage—we of the Convention Planning Committee feel that the program of exhibits, speakers, and entertainment we have prepared for you will make this, our 10th Annual Convention, the best one ever.

What airline has an expert in every job?

It's United Air Lines proud of serving you better in every way!

A while ago someone asked one of our Mainliner cabin cleaners, "Why are you so particular about getting every speck? Do you think the passengers will notice the difference?"

The cabin cleaner was surprised by the question. "You bet they will," he replied. "My passengers like to have their airplane clean, same as their homes. *They expect it on United Air Lines.*"

The remark illustrated the kind of pride you'd find in every position on United Air Lines. All of the 18,000 United people feel the same way about "Service in the Mainliner Manner."

This service makes even routine air travel suddenly become refreshingly different. Superb dependability, comfort, courtesy, convenience and speed add up to a trip that is, from beginning to end, flight at its finest! For reservations call or write United or an Authorized Travel Agent.

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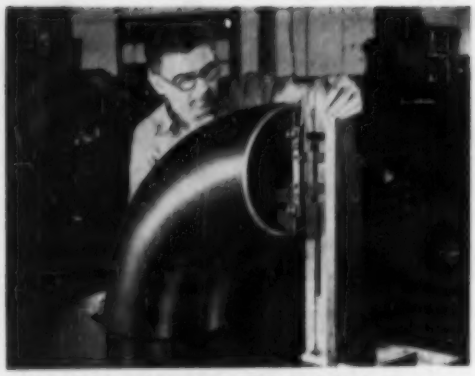
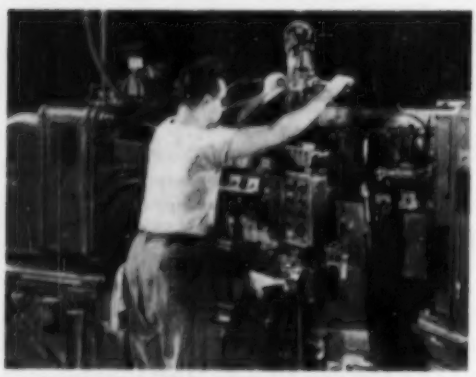
Copr. 1955, United Air Lines

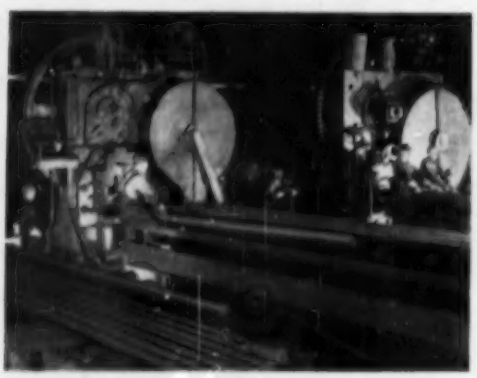
There's a difference when you travel in the Mainliner® Manner



Statistical methods in physical inspection of Ladish fittings improve uniformity of the products.



Applying quality control principles to machining assures predictably closer tolerance work.



Greater efficiency in cutting melts to length is achieved through statistical quality control.

Forging operations controlled by statistical methods result in more uniform physical dimensions.

HOW STATISTICAL QUALITY CONTROL METHODS ASSIST IN GIVING LADISH

Controlled Quality

FITTINGS AND FORGINGS INCREASED RELIABILITY

Illustrated at left are typical inspection and production operations in the Ladish plant which have been made more efficient by the application of statistical quality control.

This statistical method of quality control is incorporated into the Ladish Controlled Quality program wherever it demonstrates an ability to maintain existing standards effectively or indicates an opportunity of raising the over-all quality of operations to higher planes. It functions as one of the vital tools which build maximum reliability and dependable performance into every Ladish Controlled Quality fitting and forging.

HEAVY DROP FORGINGS UP TO 10,000 LBS.
SEAMLESS OR WELDED ROLLED RINGS UP TO 60,000 LBS
FORGED AND SEAMLESS WELDING FITTINGS

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*Deceased

Where *Quality* Became a Habit..

PIONEERING has long been a byword around John Deere factories. The steel plow with which John Deere himself conquered the soil of the Midwest's prairie land was only the first in a long list of agricultural equipment developments spread over the pages of the Company's history.

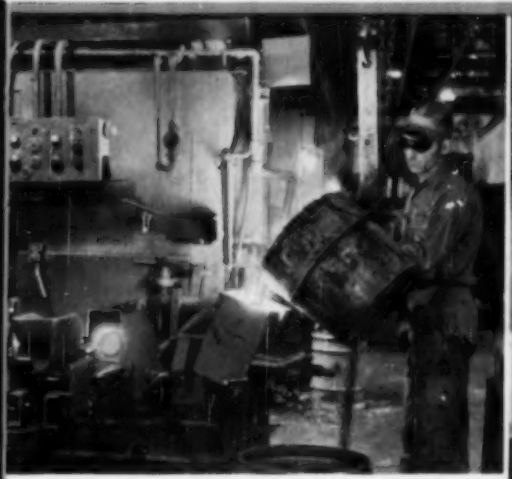
Varied as these developments were and as dissimilar in their applications, each new tool was identical with the others in one respect—quality. For the habit of quality was developed by the founder himself, left as a valued heritage to his successors, and today is maintained diligently by the thousands of people who compose the Deere organization.

It was natural, then, that in 1944, when the modern system of statistical quality control was instituted in American industry, John Deere should be among the first to recognize its value, put it in work, and encourage its adoption. Today this system is the dependable watchdog of John Deere quality and can be credited to a great extent for the continuing reputation for dependability and serviceability identified with John Deere products the world over.

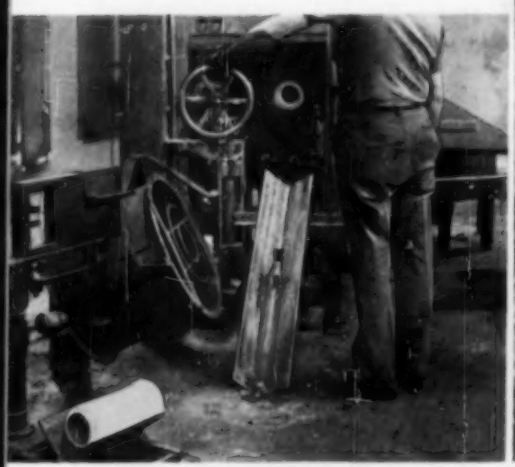
JOHN DEERE • Moline, Illinois

$(3\frac{S}{PH})(23)(8)=PCQ$

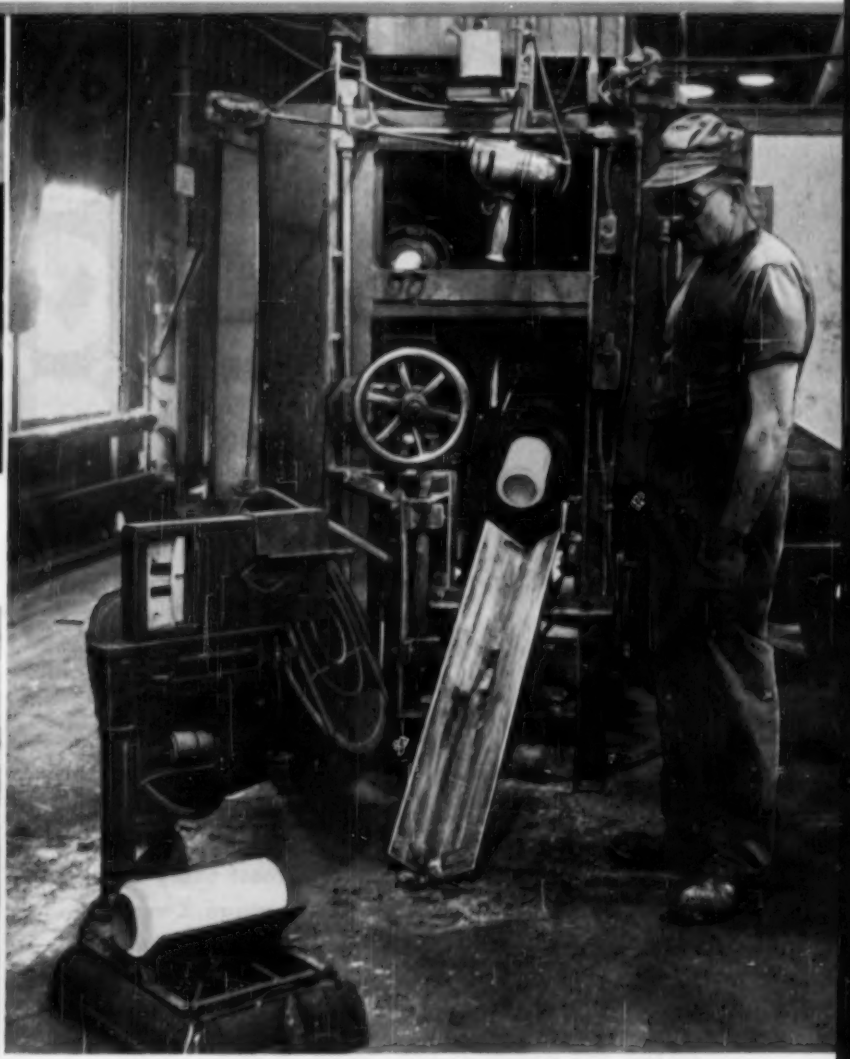
Three samples per hour are taken from each of the 23 sleeve casting spinners at Perfect Circle's Richmond Sleeve Plant. Each sample is analyzed for 8 different possible defects. Continuous process control not only assures customers castings of superior quality, it also lowers production costs.



The iron pourer pours molten metal from a conveyor ladle into a spinner ladle. Molten iron in spinner ladle is exactly the right amount to produce a centrifugal casting. White-hot casting can be seen spinning in the centrifugal casting spinner.



Cap has been removed from end of the die and the centrifugally cast casting is ready for removal. Casting on the scale is from the previous spinning operation and its weight has been verified.



Spinner operator will remove the casting on the scale and put it on a skid for transfer to the cleaning station. Casting that is being taken from one die will be caught with a hook that the spinning operator uses, placed on scale, weighed and then sent to the cleaning station.

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AUTHORIZED SERVICE and genuine Red Seal parts available from coast to coast.

In the oil field—or any other field—Continental's long experience in quality control gives you all the things that add up to dependable power. There's a Red Seal model engineered and built for almost every application in the 14-to-280 horsepower range. Overhead valve and L-head engines, for use with all standard fuels, are available as bare engines or as power units, open or closed. And Continental parts and service are available from coast to coast.

IN ADDITION TO ITS LARGE ENGINES, Continental builds an outstanding line of heavy-duty air-cooled four-cycle models for industrial and farm applications requiring 2 to 3 h.p. Advanced engineering gives them easy starting, high dependability, and unusual lugging capacity at low speeds . . . Options: patented and exclusive Contax® external ignition system, low-level ignition cut-off, 6-1 reduction gear, and other features. Available also for use on kerosene . . . For information on these models, address Air-Cooled Industrial Engine Division, 12800 Kercheval Ave., Detroit 15, Michigan.

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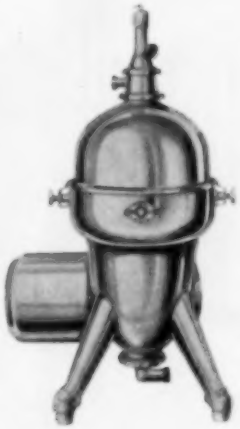

PREMIUM PRODUCT QUALITY THROUGH QUALITY CONTROL...

In 1934, De Laval introduced a new concept in milk plant centrifugals . . . a ***completely air-tight*** unit. Offering the utmost in ease of operation and sanitary handling of milk and milk products . . . this new De Laval machine immediately became standard for the industry. Today, there are more than 10,000 De Laval "Air-Tight" (R) units in American milk plants.

"Air-Tight" centrifugals are only part of the De Laval success story. Since 1878, De Laval has set the standards for industrial and milk plant centrifugals, as well as dairy and milk plant equipment.

Constant research and outstanding engineering skill permit De Laval to offer the most advanced and efficient products . . . and a highly developed Quality Control system assures purchasers of years of trouble-free operation.

At De Laval, there is no compromise with quality . . . De Laval's own high standards are rigidly maintained by Quality Control.

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Fractions defective—10% 8% 7%
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Can be passed around a group
No lost beads
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OLD EQUIPMENT MAY COST A COMPANY NOTHING—NOTHING BUT ITS FUTURE

Has it tied up the quality control engineer?

Don't look to quality control for the Midas touch. No one can guarantee consistently high product quality and efficient operation if your equipment isn't up to the job.

Today's competitive pace often demands more than outmoded production units can deliver. You dare not let quality sag even slightly while you're trying to hold a price or keep production up. If it does, a slip in sales follows. Once this happens, it may take months—or even years—to recoup.

Up-to-date equipment is the soundest solution to this problem, one in which qualified builders can be of considerable help. Working with your engineers and consultants, they have the special knowledge and resources to fill your particular equipment needs and help strengthen your competitive position. Ask them to come in and talk it over.

LUKENS ®

Lukens Steel Company, Coatesville, Pennsylvania

WORLD'S LEADING PRODUCER OF SPECIALTY STEEL PLATE • CARBON, ALLOY & CLAD STEELS • HEADS • PLATE SHAPES • FOR QUALIFIED EQUIPMENT BUILDERS

The "100,000-mile" warranty on Cummins Diesels starts here

Every component used in the manufacture of Cummins Diesels must meet exacting standards set by Cummins design engineers.

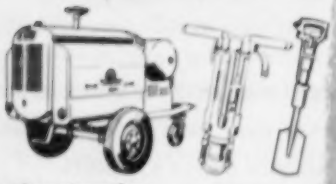
As the picture shows, finished parts are checked and double-checked for accuracy. And this is true whether the parts are to be used in new engines or sold as replacement parts.

Every shipment of steel, cast iron, or other metal is tested for quality before it is released for production. We take the time and care because we want to build the finest engine possible.

Cummins Quality Control Program, second to none, assures that every Cummins Diesel produced will give more years and more miles of trouble-free service. Cummins has such confidence in this program that it backs its engines with a "100,000 mile or one year" warranty.

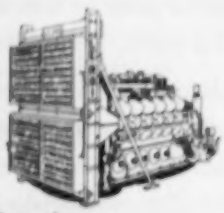
Diesel power by CUMMINS

CUMMINS ENGINE COMPANY, INC., COLUMBUS, INDIANA



For Construction

Wherever there's construction you find Le Roi Compressors teaming with Le Roi-Cleveland Air Tools to speed work and keep job costs down.



For Petroleum

Le Roi Engines work in every oil-producing area in the world — give dependable drilling, pumping, pipeline power generation etc.

For Manufacturing

Compressed air from Westinghouse Stationary Air Compressors powers myriads of tools and devices . . . atomizes liquids . . . blows soot . . . conveys materials . . . etc. Its versatility and dependability are helping manufacturing plants everywhere to increase production and lower costs. Wide use is also made of Le Roi Standby Engines, Generator Sets, and Cleveland Air Tools.

For Public Service

Le Roi Tractair — compressor tractor combination — saves taxpayers' dollars on many municipal construction jobs. Le Roi Engines power leading makes of fire-fighting equipment.

Le Roi and Its Customers Salute the American Society for Quality Control on Its Tenth Anniversary

All over the world, Le Roi equipment users are reaping the benefits of industrial quality control. They are grateful that our economic atmosphere permits and encourages quality as a major qualification for success.

Yes, from coast to coast, from country to country, Le Roi portable and stationary air compressors, Tractair, Le Roi heavy-duty industrial engines, and Le Roi-Cleveland air tools are at work on a wide variety of jobs under all kinds of conditions.

In the final analysis, it is the end user who reaps the rewards of industrial quality control procedures. That's why we extend to you a salute from our customers, too.

This tenth-anniversary celebration is especially important to us also because it coincides with our own 40th anniversary. We realize that our progress during the past 40 years is due in substantial measure to effective industrial quality control.

Now, as we offer our congratulations to the American Society for Quality Control, on its selection of Milwaukee as the headquarters city, our own quality-control procedures are being expanded to meet the challenge of the future.

Together, we look ahead.

LE ROI *Division of Westinghouse Air Brake Company*
MILWAUKEE 1, WISCONSIN

Cadillac

At Home...Among Strangers !

You're going to get a wonderful thrill when you take the wheel of your first Cadillac and head out into the country—a long, long way from home.

We're not just talking about the car's marvelous performance and its extraordinary riding and handling ease—satisfying and inspiring though these are bound to be.

We're talking about the wonderful *friendliness* you're going to encounter—about how you'll be driving among people who seem to know something about you, and who are ready to trust and respect you as if they had known you for a long, long time.

This is true, of course, because Cadillac quality and goodness have made it the overwhelming preference of people of judgment and discrimination—and the whole world has come to know and understand this and to appreciate what it means.

Yes, your best foot is forward when it rests on the throttle of a 1956 Cadillac.

We suggest that you visit your dealer soon and see for yourself. He'll be happy to give you a personal demonstration . . . and to explain why, from the standpoint of delivery and economy, this is such a wonderful time to make the move.

CADILLAC MOTOR CAR DIVISION • GENERAL MOTORS CORPORATION

Local Section News

"... BUT NOT FORGOTTEN"

ALBUQUERQUE A panel of four speakers from Sandia Corp. presented "Applications of quality control" at the Mar. 20 meeting. Phil Bircher, quality procedures division, served as panel moderator. Panel speakers and topics were: George O. Hawley, "Visual defects in metal stampings"; Aldis S. Hayes, "Control of visual defects"; Tom G. Ogden, "Statistical studies of machine capabilities"; J. Lloyd Williams, "$\bar{X}$ and R chart applications in the filling of chemical bombs." Committee chairmen and the executive committee attended a dinner-business meeting at Leonard's restaurant prior to the section meeting.

BATON ROUGE -NEW ORLEANS Prof. Richard W. Graves, DBA, MBA, statistics, presented "How large a sample should I take" at the Mar. 12 meeting which was held at Lenfant's Sea Food Restaurant in New Orleans. A dinner preceded the regular meeting.

BIRMINGHAM William B. Dunlap, chief chemist, Anniston Plant of the Monsanto Chemical Co., Anniston, Ala., was the speaker at the meeting of the section on Mar. 8. His talk, entitled "Plant standards," stressed the importance of adequate standards for control of quality operations.

The following members of the section were participants in a section sponsored QC course: (teacher) Mary Ben Rumsey; (lecturers) T. W. Young; Neil H. Zimmerman; C. M. McClendon; James E. Mitchell, Jr.; and Edwin Phelps.

BUZZARDS BAY William M. Young, manager of operations research of the Pepperell Manufacturing Co. of Boston, discussed "Evaluating industrial operations research" at the Mar. 13 meeting held in the Continental Screw Co., New Bedford. A well attended dinner at the New Bedford Hotel preceded the meeting with members and guests coming from Fall River. Mr. Young defined operations research as the quantitative approach to the solution of management problems, using the techniques of the physical and social sciences. The application of linear programming methods to problems of inventory, cost, and production control were demonstrated.

Fifteen new members were enrolled in the section, and a total of 20 registered for the basic quality control course sponsored by the section. The first lecture was given Feb. 14 and the concluding lecture Apr. 17. Lectures were held every Tuesday night in the Personnel Auditorium of Berkshire-Hathaway, Inc., New Bedford, and were arranged by Kenneth V. Chace of Berkshire-Hathaway, who is education chairman of the section. Instructors for the course were: Peter Freedman, A. Freedman and Sons; Mr. Chace; Mary Lindenberg, program chairman of the section; Walter Nichols of the Aerovox Corp.; and William Hammerly of the Pantex Manufacturing Co., Pawtucket, R. I.

CENTRAL ILLINOIS One hundred and ten persons were in attendance at the annual section meeting held Mar. 24 at the University of Illinois in Urbana. These included members of the Central Illinois section, the Kankakee subsection, the Peoria Society for Quality Control, and participants in the 9th Annual University of Illinois short course on quality control by statistical methods. Guest speakers included: H. E. Maxwell, Caterpillar Tractor Co.; R. G. Fitzgibbons, Bendix Aviation Co.; G. W. McElrath, University of Minnesota; and K. J. Trigger, University of Illinois. One of the highlights of the meeting was the presentation of a subsection charter to the recently activated Kankakee subsection. The above photo was taken during the presentation. Shown from left to right are: Milton B. Jensen, section secretary-treasurer; Rudy Peterson, subsection secretary-treasurer; Arthur Cowley, subsection past chaiman; Arthur H. Benscoter, section past chairman; George F. Schrader, section chairman; and Albert Boerckel, Jr., section vice chairman.

At the Mar. 8 meeting of the introductory education group meeting held at Navy Pier, R. A. Banzhaf of the Ordnance Ammunition Command, United States Army and co-author of Ordnance Corps manual on "Sampling inspection by variables," addressed the group on that subject.

The fourth afternoon-evening dinner meeting was held on Mar. 14 at the Furniture Club of America. The afternoon speakers were Otto Sturba of the Hotpoint Manufacturing Co. and P. Crouch of Anderson Associates. Mr. Sturba spoke on "Vendor rating" and Mr. Crouch's topic was "Linear programming."

The evening speaker was E. H. Robinson, director of quality control at the Johnson & Johnson Surgical Dressing Co. His topic was "Statistical techniques in sales forecasting." Mr. Robinson's talk was well received by all attending.

At the Mar. 20 dinner meeting of the Calumet subgroup, which was held at the Cape Cod Inn, Robert Franks of the Inland Steel Co. and Ward B. Travers of the Standard Oil Co. addressed the membership. Mr. Frank's topic was "Statistical quality control in a coke plant" and Mr. Traver spoke on "The applications of Poisson distribution in an oil plant."

CINCINNATI A sizeable number of members and guests attended the meeting on Mar. 14 to hear Ervin F. Taylor of North American Aviation, Inc., give his paper on the subject, "Discovery

sampling by attributes." This talk created much interest as was indicated by the lively and prolonged discussion which followed.

The Hamilton subsection held their regular monthly meeting on Mar. 7 as guests of the Hamilton Fisher Body Plant where an interesting talk on "Sampling" slanted toward "giving direction vendor quality" was presented by Gordon Olson, of the Ternstedt Mfg. Div. of General Motors Corp.

COLUMBUS On Mar. 21 Ervin F. Taylor, quality control analysis supervisor, North American Aviation, Inc., and vice chairman of the section, presented a paper entitled "The frequency distribution analysis sheet." This was the initial presentation and the paper carries to completion the work on graphic presentation of frequency distribution started by Arthur Bender, Jr. Mr. Taylor's analysis sheet is extended to gain such additional infomation as control limits for $\bar{X}$ and R and estimated average range.

CORNING -ELMIRA Irvin C. Kepner, of the IBM Corp. at Endicott, N. Y., was the principal speaker at the Mar. 13 meeting which was attended by approximately 50 members and guests. Mr. Kepner discussed the application of punched card machines to quality control and the many ways in which IBM utilizes punched card machines for processing quality control data.

DANVILLE -SUNBURY At the Mar. 23 meeting, Edward P. McMahon, quality control engineer at Nickey Brothers, Inc., Memphis, Tenn., spoke on "Control chart by-products," using applications from Nickey Brothers veneer and plywood operations in process, waste, and scrap control.

DAYTON The regularly scheduled meeting for the month of March was held as an all-day conference at the Biltmore Hotel, Mar. 10. This was the first all-day conference held by the section since its inception, and it proved to be very successful. One hundred and thirty were in attendance to hear the outstanding speakers that were brought in for this conference.

DELAWARE The March meeting featured both manufacturing and SQC operations at the Chrysler Tank Plant in Newark, Dela. A plant tour took place in the afternoon and a discussion of their quality control procedures was held following the dinner in the evening. Hosts for the occasion were J. S. Sheldon, quality control manager, and M. L. Joyce, assistant quality control manager. Some 650 vendors supply the 20,000 parts which go into the assembly of the 48-ton Patton tank. Assurance of quality in the final product is no small quality control problem.

ERIE On Mar. 6 we met jointly with the Erie chapter of the American Institute of Industrial Engineers. H. S. Herrick, Erie Resistor Corp., spoke on "Quality incentive plans." A lively discussion filled with repartee concerning the merit of such incentive plans brought the evening to a close. Another joint meeting is tentatively scheduled for 1956-57. Erie ASQC was the host unit at this meeting and will be guests of AIIE next year. Joint meetings with other societies are excellent for bringing a different slant on many mutual problems.

(Continued on page 82)

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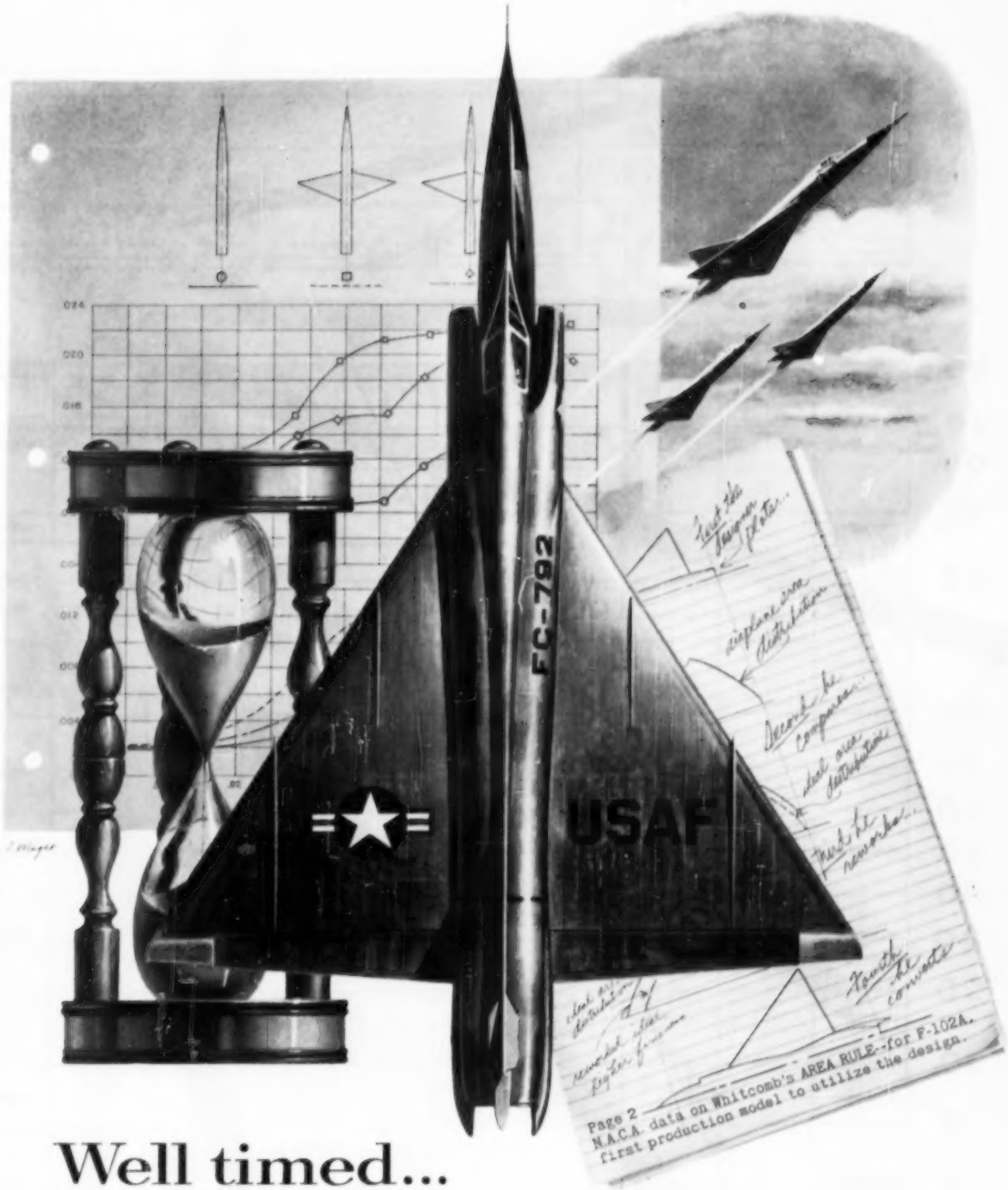

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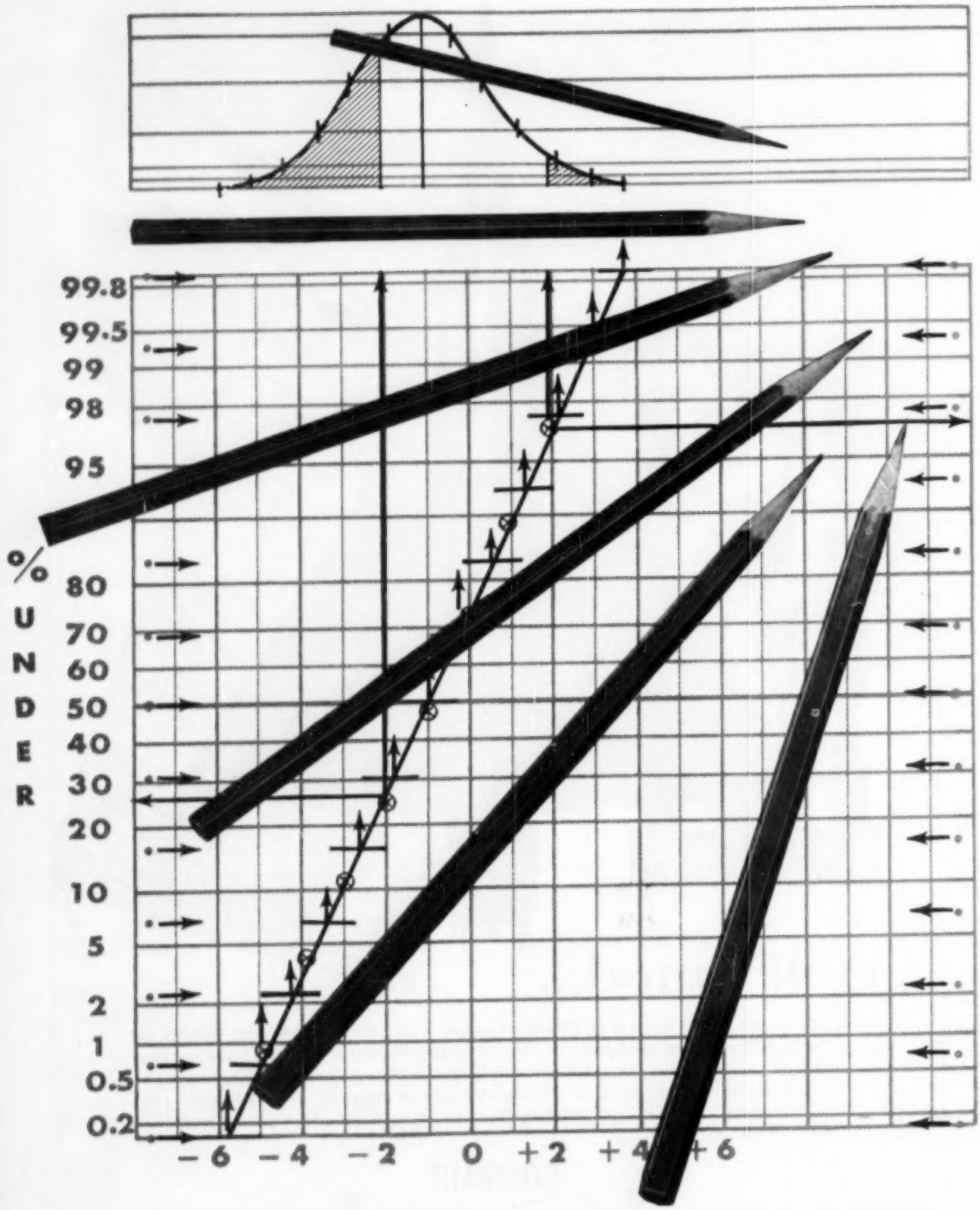
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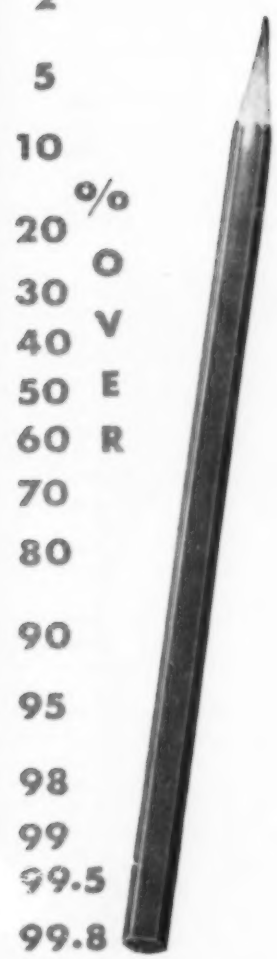

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(Continued from page 75)

GEORGIA A special meeting of the Atlanta group on Mar. 15 gave many quality control persons in the paper, clay, and chemical industries a real treat in being able to hear Carl E. Noble of Kimberly Clark Corp., Neenah, Wis., talk on "Quality control problems of customer acceptance." In his talk, he brought together the interrelation of customer needs, process capacity, and cost. Mr. Noble is the head of operations research, standards and specifications, and customer acceptance, so was able to give many interesting illustrations from his experience. A number of visitors came from the Macon subsection.

The regular meeting of the Atlanta group on Mar. 27 had to be changed from the original program. "The Hamilton lot plan" was presented by D. S. Holmes of Georgia Tech. The charts used in the July 1950 issue of *Industrial Quality Control* were projected on the screen so that the preparation could be understood. Afterwards there was a general discussion of both the advantages and disadvantages. A brief talk was given by E. G. Field on some preliminary studies of "Cycles: random and regular with synthesis" and their contributions to some quality control problems.

The basic course in quality control that was given by Don S. Holmes at Georgia Tech was very successful. He has started another evening course on sampling plans.

HARRISBURG The speaker for the March meeting was Dr. Ellis Ott of Rutgers University. His topic for the evening was "Narrow limit gaging" which prompted considerable interest among almost all present. Dr. Ott's ability as both a speaker and a lecturer, however, would provide a worthwhile program on almost any quality control subject.

INDIANAPOLIS Robert Brickley, chief of the semiconductor department, Westinghouse Corp., Pittsburgh, Pa., spoke on "How to get information from experiments" at the section's March meeting. This talk was informative both to the beginner and the man of considerable experience. Mr. Brickley outlined the steps followed when designing experiments and then gave detailed information on each step with careful emphasis on the main points. This was a joint meeting with ASA and was well attended.

An afternoon technical session held earlier was conducted by George McDermott of Delco-Remy Div., GMC., Anderson, Ind. George had case histories of a number of unusual capability studies on machines that provoked a lively discussion between Charles Hicks of Purdue, Robert Brickley, and just about everyone attending the session.

It has been decided to inaugurate an annual award to some outstanding member of the section this year. The idea grew when ways to reward a most deserving member were being discussed. A long list of devoted members who were unable to become officers because of other duties or health were recalled and it was felt that there should be a fitting award as a token of the section's gratitude.

KANSAS CITY The Mar. 14 meeting was held at the Blue Hills Restaurant. Arthur Bender, Jr., National President of the Society, was the scheduled guest speaker for the meeting, but was detained by urgent Delco-Remy business. Arnett Hamm, also of Delco-Remy, proved to be a very capable replacement in his presentation of "Kwiksee," a graphical

method of determining the characteristics of frequency distribution. Slides were used to supplement his presentation and a typical problem worked by the membership enhanced the interest in the subject.

LOS ANGELES Frank Squires of Lear, Inc., and his erudite panel of Ken Wilhite of North American Aviation and Paul Bruce of Hughes Semi-conductor Div. discussed the problems of budgeting for quality control at the March meeting.

MICHIGAN "Techniques of inspection in the paper industry" was the subject of a panel discussion held on Mar. 1 at the Wolverine subsection meeting in the Harris Hotel, Kalamazoo. This was a joint meeting with the Kalamazoo Valley Section of TAPPI with the panel composed of the following: Paul Bartholomew, Minnesota & Ontario Paper Co.; James Casey, A. S. Staley Mfg. Co.; Fred A. Beeler, Western Michigan College; and Claude Bos, St. Regis Paper Co. A crowd of 130 people attended this excellent meeting.

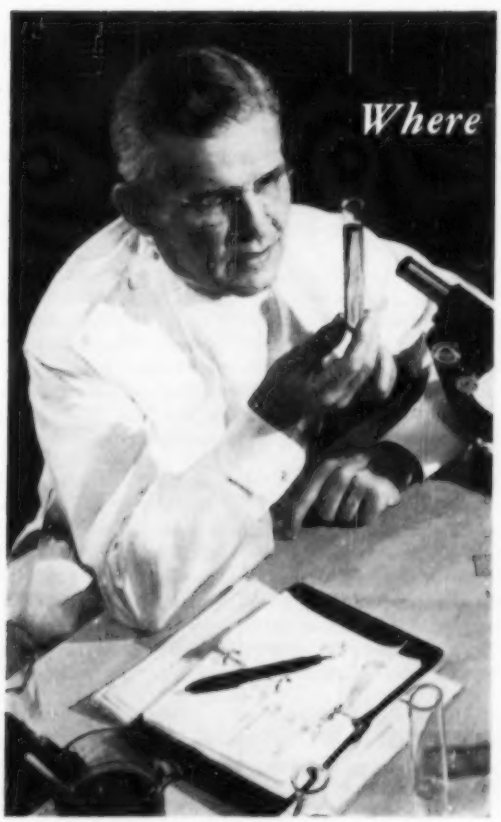
The Detroit Chapters of ACS and ASAM co-sponsored with the section a program entitled "Management night" at the Rackham Building, Detroit. Featured speaker was Donald L. Gibb, manager of plastic sales for The Dow Chemical Co., Midland. Mr. Gibb gave a fine presentation entitled "Quality control and its relationship to sales," which was followed by a number of questions from the floor.

MILWAUKEE At our February 20 meeting some 70 people braved the cold weather to hear Marvin Mundel, vice director of the Marquette University Management Center, explore "Administrative applications of quality control." Mr. Mundel, in his usual vigorous manner, reviewed the work sampling and ratio delay techniques used predominantly in the time-study field and suggested other possible uses for them. Chairman Jakel had to shut off the formal question and answer session, but Mr. Mundel didn't get away from our intellectually hungry hounds for sometime after the meeting.

The Mar. 20 plant tour and meeting at the West Bend Aluminum Co., West Bend, Wis., was a big treat for all 83 in attendance, especially the ladies. During the tour everyone saw how quality is controlled in cookware, bakeware, pantryware and appliances, and the visit through the test kitchen was particularly interesting. The country style dinner at the St. John's Church was like the "good old days"—delicious and lots of it. After dinner Linton Moths, quality control supervisor at West Bend, conducted an open forum on quality control at his company.

MONTREAL An excellent meeting was held on Mar. 21, when E. E. Schiesel, Mattatuck Manufacturing Co., Waterbury, Conn., presented a talk on "Engineering the product into SQC." For many of us this was our first contact with the subject, but Mr. Schiesel's talk proved to be most profitable.

NEW HAVEN Our Mar. 13 meeting featured Jack Silver, U. S. Census Bureau, as guest speaker. Mr. Silver's topic: "The application of statistical quality control to office operations" was most informative and enjoyed by all members and guests.



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SAN DIEGO DES MOINES

The meeting was held at the Greist Mfg. Co. and included "beer and pretzels" for refreshments.

The executive committee of the section is planning to hold their informal meetings throughout the summer months to formulate the program for the coming 1956-57 season. These informal meetings are held at committee members' homes regularly each month.

NORTHEASTERN INDIANA The presentation given Mar. 8 by John Harrington, chief engineer-gaging dept., DoALL Gage Co., on the subject of "Technique of surface grinding" was of real interest and value to those in attendance at this meeting.

Mr. Harrington's presentation included suggestions which quality control people in plants where grinding is an important part of their operation would be well to remember, especially when confronted with problems of quality grinding.

Of particular interest was his suggested methods of increasing the number of quality parts from a grinding wheel through the use of atomized coolants.

Mr. Harrington's talk was enhanced through the use of a sound film demonstrating the balancing and dressing of wheels and the setting up of grinders for best results.

ROCHESTER A record attendance of 853 braved a bad snowstorm to attend Rochester's 12th annual clinic. A total of 22 speakers presented a diversified, well-rounded program.

The luncheon speaker, Dr. Henry C. Mills, vice president for educational administration, University of Rochester, provided one of the highlights. In his talk, "Meeting demand for engineers," Dr. Mills brought out many of the facets of this timely problem. He pointed out the need for close cooperation between industry and educational institutions and by this very talk improved this relationship.

Dr. Emmett K. Carver, technical assistant to the general manager, Kodak Park Works, climaxed an outstanding day as the dinner speaker. "Organization, personalities and creative thinking," was Dr. Carver's topic. He discussed the vital task of organizing and administering technical operations. To say that this thought-provoking talk was well received would be putting it mildly.

On Mar. 6 C. G. McClure, application engineer, Sperry Products, Inc., addressed the gaging and measurement sub-group of the section on "Nondestructive testing."

Management of the quality control function" was discussed by A. V. Feigenbaum, manager quality control and cost reduction, General Electric Co., on Mar. 20. The interest shown during the question period following this stimulating talk was unusually keen.

ST. LOUIS At the March meeting Professor David S. Chambers of the University of Tennessee, Knoxville, Tenn., gave a most interesting discussion on the meaning of certain basic probability concepts on the use of several special techniques. Off square dice and chips formed the basis for interesting experimental data. The group was interested to learn that special, made to order, non standard dice were obtainable in St. Louis.

SOUTHERN CONNECTICUT "Stamford night" was held on Mar. 14 by the section at the Pitney-Bowes, Inc., Stamford. Joseph Lewis, quality control manager, was host to the section. The speaker was W. A. MacCrehan, quality con-

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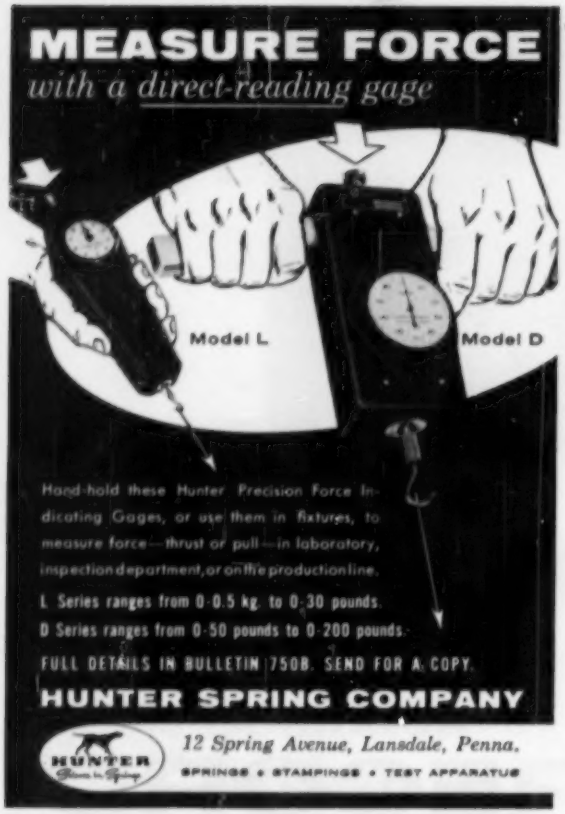
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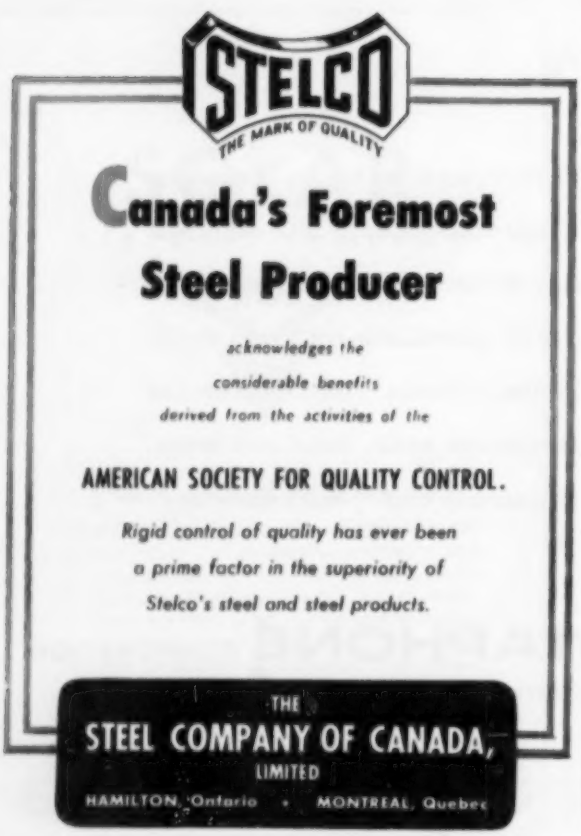
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trol engineer of Bendix Radio Div., Bendix Aviation Corp., Baltimore, Md.

Mr. MacCrehan spoke on "Evaluating vendor quality" and presented the way his company handled this problem. His talk was excellent and created considerable interest, as was evidenced by the many questions fired at him during the question period. This meeting in Stamford was the section's way of saying thanks to the many loyal members from the Stamford area for their support of the section.

SOUTH TEXAS For those of us who were called on from time to time to submit cost estimates (and there are few, if any, exceptions), the talk given by W. N. Smith of Dow Chemical at Freeport, Texas, was outstanding in its helpfulness. Mr. Smith was forced to do some original thinking to develop the technique and, as most original thinkers might suspect, Mr. Smith's talk invited a longer than usual "question and answer" period. We look forward to his return as a speaker.

TENNESSEE
Memphis Subsection Major G. A. Johnson, plans div., procedures branch, quality control headquarters, Air Material Command, Wright Patterson Field, Dayton, Ohio, spoke on the subject "Air Material Command, procurement quality control systems" at the Mar. 27 meeting. A special steak dinner preceded the meeting which was held at the Mallory Air Force Depot Officers' Mess.

TOLEDO On Mar. 14, the section travelled to the Sylvania Electric Products Co., Ottawa, Ohio. The Ottawa Plant produces television tubes. Bob Barr, quality control manager at Sylvania, played host to the section. The plant tour was preceded by dinner in the plant cafeteria.

WICHITA A color sound film "This is life" on the processing of meat from the hoof to the table was shown at the Mar. 6 meeting held at the Oriental Cafe. Dave Smith, personnel director for Cudahy Packing Co., presented the film and gave a short talk on quality control in the meat packing industry. D. E. Hillman was the program chairman.

WINNEBAGO The regular monthly meeting was held at the Elk's Club, Appleton. The guest speaker for the evening was L. C. Paulson, quality control supervisor, Minnesota & Ontario Paper Co. His talk was titled, "A quality control program for the paper industry."

A training session conducted by Dr. Carl Noble preceded the regular meeting.

WORCESTER Dale L. Lobsinger, supt. of quality control at United Airlines, Inc., Denver, Colo., presented a talk on "SQC applied to administrative areas" at the Mar. 15 meeting. His talk was very interesting, especially his line of approach to clerical errors, supervisory problems, and absenteeism.

Preceding the meeting, Mr. Lobsinger met with the section's officers to obtain their suggestions and questions pertaining to the overall organization of the Society. This informal meeting was beneficial to the section in that it gave the officers a chance to get first hand information on Society activities and voice opinions on various subjects.

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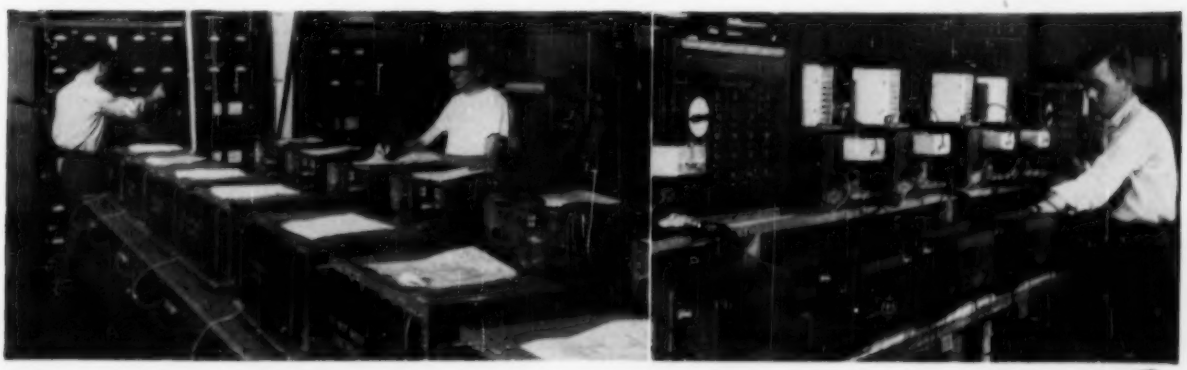

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YOUNGSTOWN A good turnout was on hand to greet Dr. W. J. Youden and listen to a fine talk on "Design and analysis of experiments" at a dinner meeting held in the Mural Room of the VFW. The subject matter was of real interest to our group as individuals, evidenced by the many questions raised at the end of Dr. Youden's talk.

". . . CAST THEIR SHADOWS BEFORE"

ALBUQUERQUE Dr. Leslie W. Ball, technical director of the United Electrodynamics Division, United Geophysical Corporation, who was originally scheduled as speaker for the April meeting, will be the guest speaker for the June meeting.

BIRMINGHAM On May 24 the chairman of the Birmingham section will be host at a dinner meeting of the incoming and outgoing officers. At this meeting the outgoing officers will pass along to the incoming officers any information which may be helpful in getting the new officers off to a good start.

CHICAGO On May 23 at the "do-it-yourself" meeting which will be held at Navy Pier starting at 7:30 pm, Ralph Haertel, quality control engineer of the Stewart Warner Corp., will present a problem related to the fabrication of speedometers. For audience analysis, this should prove very interesting.

On May 24 the introductory education group will meet at Navy Pier. The time of the meeting will be 7:30 pm.

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The section's annual social and dinner meeting for members and their wives or guests will be held on June 1. Presently, Bob Tenney, program chairman, is in the process of arranging the place and evening's hilarity. Don't forget the date, June 1.

COLUMBUS R. W. McCormick, packing engineer, Westinghouse Electric Corp., will present a talk entitled "Pre-shipment testing" at 8:00 pm on May 23. Mr. McCormick's illustrated talk will demonstrate the precautions which are taken to insure that an undamaged article is delivered to the customer.

DELAWARE The May meeting of the section completes the schedule of regular meetings for the season. The executive committee will meet monthly during the summer to complete plans for the next season.

GEORGIA The last of the spring meetings of the Atlanta Group on Tuesday, May 29, is of special importance. Robert G. Mitchell, quality manager of the International Latex Corp., Dover, Dela., will speak on "Quality control—the seeing-eye of production," and tell of some experiences in the practical application of quality control.

An interesting program for the fall meetings of the Atlanta Group has been completed and is ready for early release.

HARRISBURG The June meeting will consist of a series of problem solving sessions relative to various areas of interest. It will be held at the Indian Echo Hotel in Hummelstown.

KANSAS CITY The last meeting of the season will be held June 13. The Blue Hills Restaurant will be the location of this dinner meeting. Included in the business will be the report by those attending the National Convention and a final reporting of membership and finance programs during the past season.

MILWAUKEE The May 21 meeting is our local talent and problem night! A panel of locally prominent members will discuss quality problems presented by the other members. The meeting will be held in the Stratford Hotel, Milwaukee.

The Annual Business Meeting and Social of the Milwaukee section will be held at the Miller Brewing Co. on June 18. A pre-meeting plant tour is scheduled followed by a buffet-dinner. A gala time for the finest people we know is a certainty. Those who attended our last meeting at the home of Miller High Life would certainly recommend that this meeting will be an excellent close to a very successful year.

NORTHEASTERN INDIANA On June 14 the executive council and newly elected officers will hold their annual organization meeting. This will conclude the activities of the 1955-56 season. The 1956-57 season will again convene on the second Thursday of September, at 8:00 pm, at the Chamber of Commerce, Fort Wayne.

TOLEDO The section plans for the May meeting include a talk by Dr. J. H. Toulouse on "Tests of significance." Following the educational section, will be a divisional panel discussion covering related subjects to cover all interests. The meeting will be preceded by dinner at Angelos.

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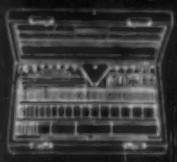

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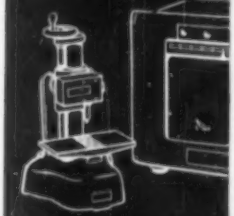

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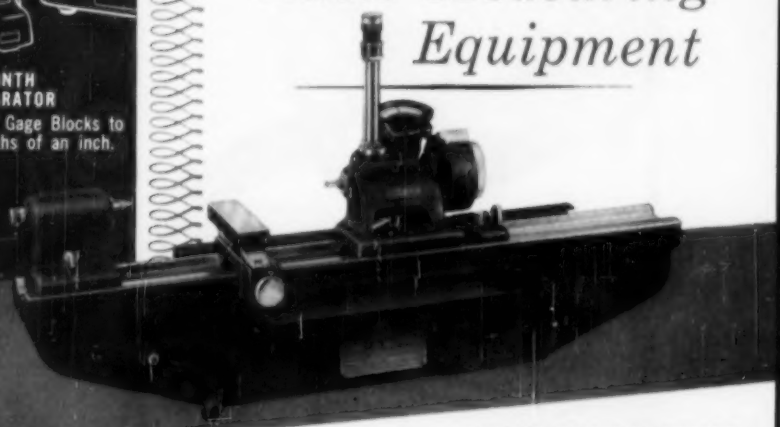

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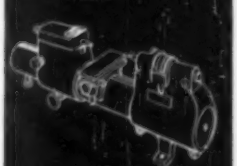

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WINNEBAGO Plans are being made to have the June meeting designated "Ladies Night." A program which will give the wives a clear understanding of what a quality control program consists of is being worked on by the program committee.

"AS YE SOW . . ."

SOUTH TEXAS A two weeks course in Statistics to be conducted by the University of Oklahoma, Norman, Okla., has definitely been set for July 9-20. The course is being co-sponsored by the Chemical Division and will *not* be, as announced in the February issue of IQC, an advanced course. It will, however, be aimed at the chemical engineer and chemical technologist. Four excellent instructors for the course have already been selected. They are: Gayle McElrath, University of Minnesota; D. J. Kaufmann, Washington University, St. Louis, Mo.; Oscar Kempthorne, Iowa State University, Ames, Ia.; and G. C. Brixey, University of Oklahoma.

During the first week of the course the topics "Basic concept of statistics," "Significance testing," "Sample requirements," "Control charts for variables," and "Collection of preliminary information" will be taught by Profs. Kaufmann and Brixey.

During the second week, Profs. McElrath and Kempthorne will cover "Regression in correlation analysis," "Experimental design," "Analysis of data" and "Selection of design."

Registration fee for the course will be $150 and contact will be made by direct mail only. Further information can be obtained by contacting either Dr. R. L. Huntington, Research Professor, College of Engineering, University of Oklahoma or M. L. Powers, Director of Business and Industrial Services, Extension Division, University of Oklahoma.

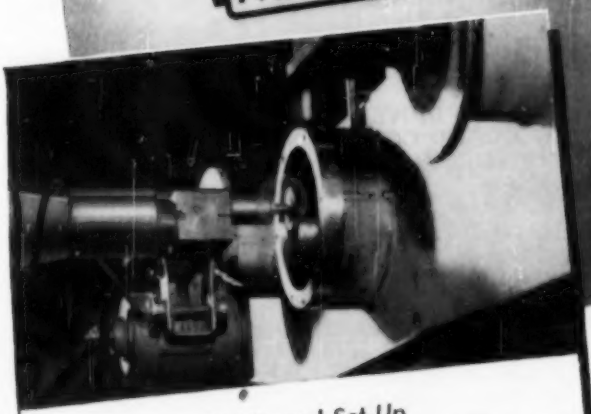
Dr. Huntington recently held a planning meeting for the course with Edmond S. Aldredge, Carbide & Carbon Corp., Texas City, Texas; William S. Sevier, Monsanto Chemical, Texas City, Texas; and Charles T. Shewell, Humble Refining Co., Baytown, Texas, all members of the South Texas Section.

WESTERN REGIONAL CONFERENCE AUGUST 20-21 The Los Angeles section will be host to the Third Annual Conference of Western Region Sections. This year's conference will be held Aug. 20-21 at the Statler Hotel in Los Angeles and will be sponsored by the Los Angeles Section and the Aircraft Division. The primary objectives of the conference are to acquaint industry and the public with the fundamentals of quality control and to have technical sessions for the presentation of papers of basic and advanced techniques of quality control. The conference program also includes two technical luncheons, a banquet, and a ladies program for wives who accompany out-of-town delegates.

To create interest in the conference, the slogan "Increase sales through quality control" has been adopted.

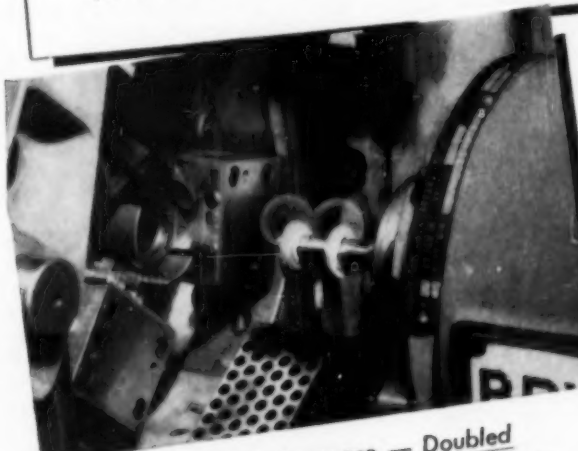
For the presentation of technical papers, the conference will be divided into three sections; aircraft and missile; technical; and general development. There will be two sessions of approximately 90 minutes each in the morning and afternoon of both days. The papers presented will range from basic fundamentals to advanced techniques. In order that participants may be able to choose wisely from the wide variety of papers to be presented, advance notice of subject matter and speakers will be mailed out in June.

The INSIDE STORY of INTERNAL GRINDING by NORTON



An Unusual Set-Up

Grinding bearing housings with a Norton wheel on a Dumore tool post grinder, mounted on a horizontal boring mill. The grinder itself revolves in a planetary motion, the grinding wheel spindle following the I.D. of the hole. To grind the other end of the housing the work table is turned 180°. *Material:* cast steel. *I.D.:* 7.8737". *Stock removal:* .005" each end. *Limits:* +.0001", —.0004". *Time:* two hours each end.



Precision Performance — Doubled

Here a Norton two-wheel set-up is ready to go into fast grinding action. The job is grinding a double race in a steering gear bearing. *Material:* SAE 1045 steel, 54 Rockwell C. *I.D.:* 1.1507". *Stock removal:* .012". *Limits:* +.0000", —.0005". *Finish:* 10 microinches RMS. *Time:* 60 seconds.

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To lend prestige and support to the conference, several nationally known speakers from industry including aircraft will speak at the luncheons and banquet. The roster of speakers will also include nationally recognized leaders in the educational field.

For further information, write: E. C. Bennett, 9226 8th Ave., Inglewood, Calif.

MANAGEMENT COURSE JUNE 11-23

The college of engineering, State University of Iowa, announces the seventeenth Management Course to be held June 11-23 in Iowa City. In addition to the intensive course of instruction, a series of talks will be given by recognized authorities on new developments, applications, and problems in management techniques. The entire program is designed for those who have need to use these techniques —factory managers, foremen, industrial engineers, methods and time-study analysts, cost men, office executives, and others in related work.

The areas of production planning, job evaluation, motion and time study, wage incentive, plant layout, materials handling, quality control, supervisory training, labor relations and legislation, organization and policy, engineering economic analysis, and public speaking are included.

The regular State University of Iowa teaching staff will be augmented by outstanding men from a variety of industries and other educational institutions.

Communications concerning the course should be sent to J. Wayne Deegan, 122 Engineering Building, State University of Iowa, Iowa City, Iowa.

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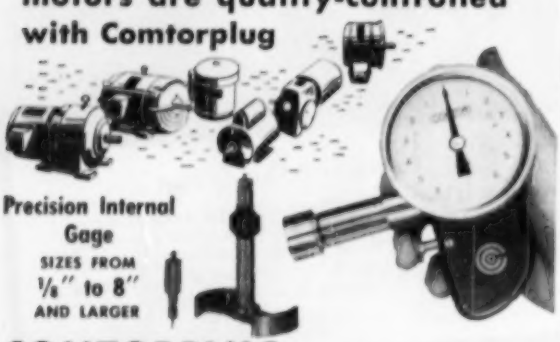

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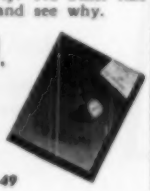

GET THE FULL FACTS — REQUEST BULLETIN 49

PURDUE UNIVERSITY ADVANCED COURSE JUNE 12-22

The tenth annual advanced course in "Quality control by statistical methods" will be held June 12-22. The course is intended for those who have already had an elementary course and wish to go on to more advanced techniques.

The course has been lengthened to ten days and the notes revised. The aim is to include much more analysis of variance and some design of experiments. Other topics include significance tests and estimation, acceptance sampling by variables, sequential analysis, linear and multiple correlation, and tolerances for mating parts. This course is under the direction of Professor Irving W. Burr and will include on the instructional staff Professors Cecil C. Craig, Charles R. Hicks, Floyd A. Knowler, Edwin G. Olds, and Mason E. Wescott.

Further information may be obtained from Prof. Burr at Purdue University, Lafayette, Indiana.

RUTGERS UNIVERSITY ADVANCED COURSE SEPTEMBER 5-12

A six-day "Advanced course in quality control by statistical methods" will be offered by Rutgers University at Newark, N. J., Sept. 5-12, 1956. The regular Rutgers Basic Conference Series will be given on nine consecutive Wednesday afternoons and evenings from Mar. 20 thru May 15, 1957.

The advanced course is designed to provide additional instruction for persons who have had a basic course and industrial experience in the SQC field. It will include advanced topics in SQC such as sampling by variables, sequential analysis (both attributes and measurements), narrow-limit gaging, tests of significance, regression and correlation, chi-square, basic experimental design, analysis of variance, and the organization and management of a quality control program.

The full-time Rutgers staff members who will be associated with the advanced conference are: Professors Allen R. Crawford, Ellis R. Ott, and Mason E. Wescott.

Tuition is $150, which includes text and instructional material. For additional information write to Allen R. Crawford, Course Coordinator, University College, Rutgers University, New Brunswick, N. J.

UNIVERSITY OF MICHIGAN SHORT COURSE AUGUST 20-30

The University of Michigan has scheduled its ninth annual ten-day intensive course in quality control by statistical methods for Aug. 20-30, on the campus in Ann Arbor. This is a first course for executives and supervisory personnel; it is practical and mathematically non-technical. It includes the standard control charts and sampling acceptance plans together with other basic techniques.

Instruction includes lectures, demonstrations, practice sessions and conferences. The staff will include Professors E. G. Olds, Carnegie Institute of Technology; M. E. Wescott, Rutgers University; and C. C. Craig and E. C. Yehle, both of the University of Michigan. The fee will be $125.

Please address inquiries to the course director, Prof. C. C. Craig, 106 Rackham Building, Ann Arbor, Mich.

UCLA SHORT COURSE AUGUST 6-17

The Department of Engineering, University of California, Los, Angeles, in cooperation with University Extension and the Los Angeles section of ASQC, is inaugurating a course devoted to "Statistical methods in industry." This is a full-time program from eight to five for ten days dur-

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ing the period Aug. 6-17. Participants may register for one of two concurrent courses: a basic course in quality control by statistical methods and an advanced course in industrial statistical methods. In addition, there will be presented a series of ten general lectures for all participants on the subject of reliability in industry and five general lectures on such subjects as statistics in research, standards and gaging in inspection, quality control procedures, organizations, and reports to management. This course will be of interest to a broad class of individuals in industrial and governmental organizations concerned with analysis of reliability problems in research, design, development, and production. These individuals include quality control engineers, inspectors, quality directors, and other line and staff personnel. The $250 fee for the course includes tuition, books, supplies, ten luncheons and one dinner. Included in the staff will be Professor Irving Burr of Purdue University and Professor Lloyd Knowler of the State University of Iowa. For further information write Professor Edward P. Coleman, Department of Engineering, University of California, Los Angeles 24, Calif.

GRADUATE SUMMER SESSIONS IN STATISTICS JUNE 11 - JULY 20

The University of Florida, North Carolina State College, Virginia Polytechnic Institute, and the Southern Regional Education Board are jointly sponsoring a series of cooperative summer sessions in statistics.

The third of these summer sessions will be held at North Carolina State College, June 11-July 20. A session is scheduled to be held at Virginia Polytechnic Institute in 1957 and at the University of Florida in 1958. Each summer session lasts six weeks and each course carries approximately three semester hours of graduate credit.

Courses to be offered this summer are: statistical methods I; statistical methods II (design of experiments); statistical theory I (probability and parent distribution); statistical theory II (sampling distributions and inference); sample survey designs; advanced analysis II; advanced calculus for statistics; stochastic processes; econometric methods and linear programming. Lectures on linear equations, (matrix algebra) and production functions will be given in the institute program.

Inquiries should be addressed to: Professor J. A. Rigney; Department of Experimental Statistics; North Carolina State College, Raleigh, North Carolina.

OPERATIONS RESEARCH JUNE 4-15

The operations research group of the department of engineering of the Case Institute of Technology is offering a two-week short course in Operations Research, June 4-15. The objective of the course is to provide a short intensive survey of methods, techniques, and tools of operations research with emphasis and applications to business and industry. Case histories will be used extensively. The course will provide a foundation for development of technical competence but will not itself provide such competence. It is designed to produce an understanding of how and where operations research can be used.

Course prerequisites are research experience and sufficient knowledge of mathematics to understand mathematical symbolism. Mathematical derivations will not be emphasized.

The fee for the course is $325 which includes all instructional fees, ten luncheons, 6 dinners or picnics.

lecture notes, texts, and supplies. Living quarters will be available at a reasonable rate. Registration will be limited to the first 50 qualified applicants.

Inquiries and registrations should be addressed to W. W. Abendroth, Operations Research Group, Engineering Administration Department, Case Institute of Technology, 10900 Euclid Avenue, Cleveland 6, Ohio.

LINEAR PROGRAMMING MARQUETTE UNIVERSITY JUNE 12-14

An introductory course in Linear Programming is being offered by the Management Center of Marquette University, June 12-14. The course will deal with mathematical methods of developing solutions to complex management problems such as product mix, machine loading, warehouse utilization, and shipping and delivery patterns.

The course contents are being evolved with the help of Professors Talacko and Golomski of the Marquette University Department of Mathematics. The course fee is $54 which includes lunches.

For registration and additional information, write: Dr. Russell L. Moberly, Director, Management Center, College of Business Administration, Marquette University, Milwaukee 3, Wis.

MOTION & TIME STUDY COURSE JUNE 6-15

A Motion and Time Study Intensive course offered by the Department of Industrial Engineering of Washington University in St. Louis will be presented from June 6-15. This course is intended for personnel desiring a basic introduction to motion and time study.

This course is being presented with the cooperation of the St. Louis chapters of the American Institute of Industrial Engineers and the Society for Advancement of Management. For further information concerning course content, instructors and registration write to the Department of Industrial Engineering, Washington University, St. Louis 5, Missouri.

MARQUETTE UNIVERSITY QC SHORT COURSE JUNE 18-29

A two week short course, "Introduction to quality control by statistical methods," covering the basic techniques, basic charts, sampling, applying, and controlling aspects of quality control, will be conducted at the Marquette University Management Center, June 18-29. The conference director is Dr. M. E. Mundel.

The course is designed to offer the enrollees an opportunity to familiarize themselves with fundamentals; examine sample problems; become acquainted with the latest thinking and techniques in the field; broaden their concept of the use of statistical methods; and discuss common problems.

The staff is comprised of Professor Gayle McElrath, University of Minnesota, and Harmon S. Bayer, quality control consultant from Detroit, Mich. The full time staff will be assisted by numerous guest speakers from industry.

The course fee is $180.00 which includes all materials and ten lunches. The enrollment is limited. For registration or further information, contact: Dr. Russell L. Moberly, Director, Management Center, College of Business Administration, Marquette University, Milwaukee 3, Wis.

(Continued on page 98)

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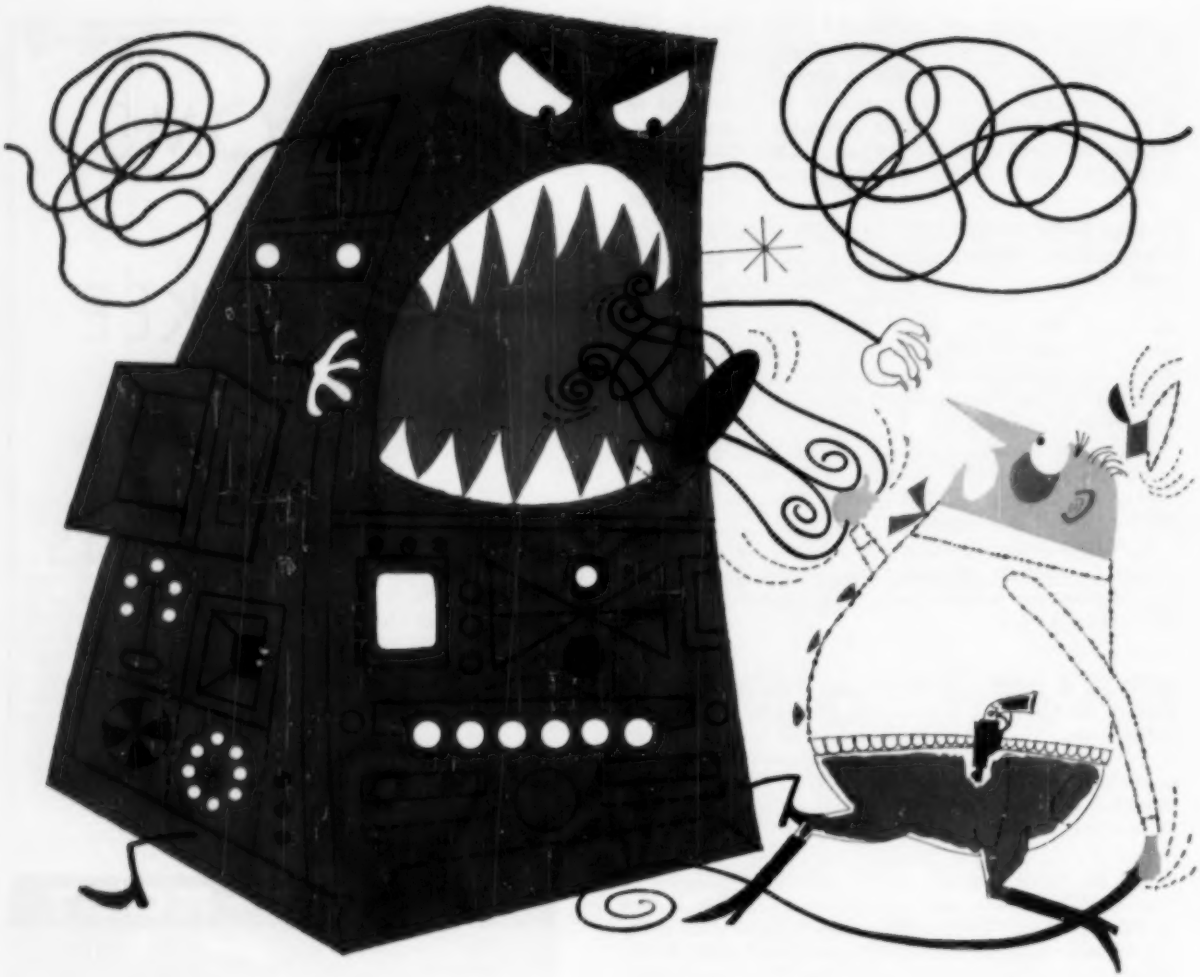

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NEW G-E Thickness Gage Gives Faster Product Inspection

General Electric's new permanent magnet thickness gage speeds production testing and helps assure you quality production and savings in materials. It is portable, self-contained and small enough to hold in your hand.

The new gage gives non-destructive thickness measurements of non-magnetic coatings, such as paint or plating, on magnetic iron or steel. Other non-magnetic materials—plastic, celluloid, mica, and paper—can also be measured when placed on a smooth, magnetic plate.

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For further information on the PM thickness gage contact your nearest G-E Apparatus sales office, or write for bulletin GEA-6458 to Section 585-51, General Electric Company, Schenectady 5, New York.

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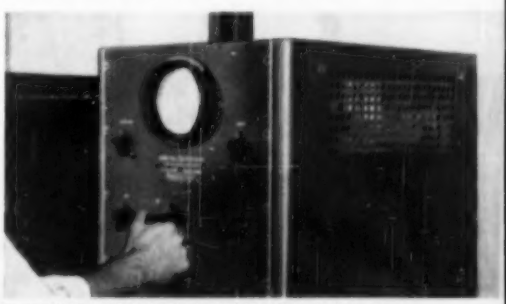

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Standard of the World

(Continued from page 95)

"FOR MANY ARE CALLED, BUT FEW ARE . . ."

CINCINNATI Hamilton Subsection The election of officers for 1956-57 was held at the conclusion of the Mar. 7 meeting. Officers elected were: chairman, Keith Sherck, Pillsbury Mills, Inc.; vice chairman, Gordon Thompson, Champion Paper & Fibre Co.; secretary, Robert Merrill, Whirlpool-Seeger; treasurer, Robert Bastian, Bendix, Corp.

DELAWARE Frank J. Valentine of Atlas Powder Co. has been appointed section treasurer to complete the unexpired term of Ted H. Crommer, who has been transferred from this area.

GEORGIA The Atlanta group at their regular meeting on Mar. 27 elected the following officers for the coming fiscal year: chairman, Donald S. Holmes, Engineering Experiment Station, Georgia Institute of Technology; vice chairman, Harry O. Fewox, Staff Statistician, Southern Bell Telephone & Telegraph Co.; and secretary-treasurer, E. G. Field, E. G. Field & Associates.

LOS ANGELES The following were elected to serve as officers for 1956-57: chairman, Dr. Leslie W. Ball, United Geophysical Corp.; vice chairman, Dr. Leo A. Aroain, Hughes Aircraft Co.; secretary, Henry Matosoff, Firestone Tire & Rubber Co.; Halmond L. Parks will continue as treasurer.

MICHIGAN The new section officers were announced at the Mar. 16 meeting. They are as follows: chairman, Dr. E. C. Yehle, University of Michigan, Ann Arbor; vice chairman, Harmon S. Bayer, quality control consultant, Detroit; secretary, S. J. Adams, Wolverine Tube Division, Detroit; treasurer, W. J. Gallagher, Ford Motor Co., Detroit.

MEMBERSHIP CORNER

Sam Oliva, member of the National Membership Committee, submits the mid-year letter given below as an example of membership activity for a very active section.

Many sections suffer from organizationalitis as they get larger and one of the major complaints that the members have is that the personal touch is gone. The mid-year letter (some sections make this a monthly news-letter) is an excellent way to dispel the idea that the Society is impersonal and formal. We pass this on as an excellent idea for your section to entertain.

SOUTHERN CONNECTICUT SECTION
* * * MID-YEAR LETTER * * *

Before the first month of 1956 rolls away into history, your Executive Committee and I wish to take this opportunity to extend to each of you our cordial wishes for a happy and prosperous new year.

It is indeed a satisfaction to know that these greetings will reach 137 members. We are happy with the final membership figure reported by Membership Chairman Stu Lyle; however, in this A.S.Q.C. anniversary year, we have our sights set on a possible 150 for a 1956 membership total. Will you help us?

(Continued on page 104)

There's a long history of quality control back of the CANCO oval!

Every container that bears this famous trademark is manufactured under a comprehensive quality control program. Many years ago, American Can Company established a policy of highest possible product standards. Today it is a Canco tradition.

Quality control men in the many Canco plants throughout the nation assure Canco customers of highest quality containers, be their requirements large or small. Such outstanding day-in, day-out dependability plus the newest and best in packaging ideas keep Canco first.

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COLUMBUS SECTION
A. S. Q. C.
ANNOUNCES
FOR DECEMBER 1, 1956
A ONE DAY CONFERENCE ON THE THEME
"SPECIFICATIONS FOR Q. C."

THE CONFERENCE IS PLANNED AND SHALL BE CONDUCTED BY REPRESENTATIVES FROM THE FOLLOWING INDUSTRIES IN CENTRAL OHIO AREA.

NAME	PRODUCT
American Blower Corp.	Heating & Blower Equip.
Anchor Hocking Glass Co.	Glass Products
General Electric	Electric Consumer Products
General Motors Corp.—Ternstedt Div.	Auto Parts
Hazel Atlas	Glass Products
Jeffrey Manufacturing Co.	Conveyor & Mining Equip.
Marion Power Shovel	Power Shovels
M. & R. Dietetic	Milk Preparations
Mead Paper Co.	Paper Products
North American Aviation Co.	Aircraft
Owens Corning Fiberglas	Fiberglas Products
Owens Illinois	Glass Products
Ranco Inc.	Refrigeration & Heater Controls
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Westinghouse Electric Corp.	Refrigerators

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As evidence of this research and development, Johns-Manville announced late last year the opening and dedication of what will be the world's largest asbestos mill. This Johns-Manville mill, the first half of which is illustrated, is located at the J-M Jeffrey Mine at Asbestos, Canada, the world's largest asbestos mine.

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American Society for Quality Control
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Milwaukee 3, Wis.

(Copies are available only to members of ASQC)

A New Holland Quality Control Inspector examines teeth of a main drive pinion that will go into Model 87 hay baler.

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DOWN TIME IN A HAY FIELD

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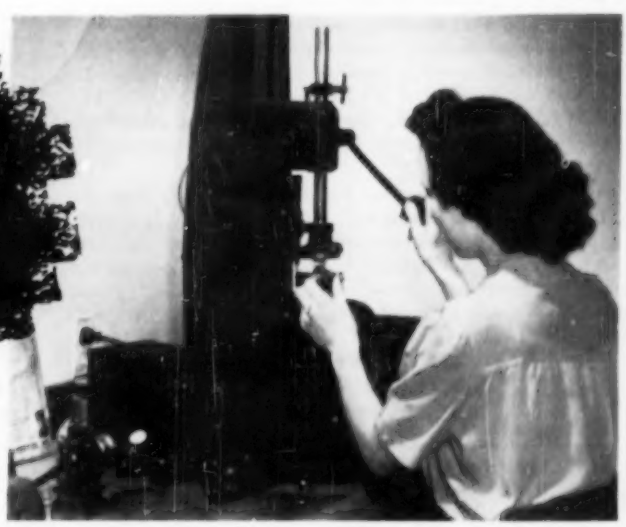
Accurate Springs



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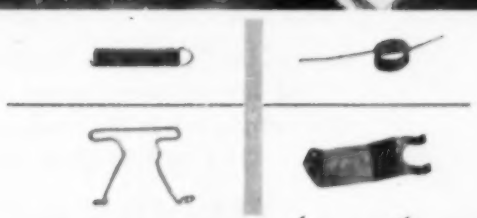

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Accurate Springs

(Continued from page 98)

Look around your plant at this half year time. Isn't there someone you can interest in A.S.Q.C. membership? Half-year membership is $5.00 you know—a good talking point. A glimpse at our program for the remaining months should sell anyone.

I know you are interested in our progress toward the Saddoris Award. We have taken advantage of every opportunity to pile up points for leadership in section management. Your loyal, regular, and enthusiastic attendance at our meetings is our strongest asset. No need to tell you how much this has been appreciated!

We have often suggested that you can gain most from your A.S.Q.C. membership by indicating to me, or to the heads of any of the listed committees, that you are interested in serving on a committee. We have particular need now of a member to serve as chairman of a new committee which would coordinate local and national effort to secure advertising for our magazine, *Industrial Quality Control*. The formal solicitation for an ad comes from the Milwaukee office. However, there is need of local effort and follow-up, and we ask that one of you spearhead this extremely important national project on a local level for us. Call your Chairman, (AM 8-9652) and volunteer your services. Discover the satisfaction and the excitement that come from working first hand with one of the fastest-growing, most progressive societies in the country.

Tom Ragona, Publicity Chairman, is up and around again after having been hospitalized as a result of a December automobile accident. He has the best wishes of all of us for a full recovery, and I am sure he also has the cooperation of the entire membership in his constant search for material for publication in *Industrial Quality Control*. Call or write Tom and let him know of any news that he can use.

Before our next meeting, we should like to stress the importance of making your dinner reservations with Frank Walsh as early as possible. If you should discover that you cannot attend, PLEASE CALL TO CANCEL YOUR RESERVATION. We lost $89.50 on the otherwise highly successful Scovill Plant Visitation because of this oversight.

A final happy note—our February meeting promises to be the most interesting yet. Mr. D. N. Smith, Manager of Research Engineering of the Jones and Lamson Machine Co. in Springfield, Vermont, and the originator of the concept of "Pre-Control", will be our guest speaker. I look forward to geeting each of you personally on February 8th.

Cordially yours,
E. W. DEMERS, Chairman
Southern Connecticut Section

"WHAT ARE YOU AFFECTIONATELY KNOWN AS TO YOUR MEN."

The following letter has been received from Ralph D. Humphries, district representative, District 13. He calls attention to the remarkable growth in this district and the Membership Committee wishes to give both Mr. Humphries and the district our sincere thanks.

"After reviewing the membership report as of December 31, 1956, I would like to mention . . . that District 13 was the only District where every section in the district has increased their membership over that of June 30, 1955. District 13 has increased their membership 26 percent more than any other district. One section (Wichita) in the district has a membership increase of 59 percent which is 11 percent higher than any other section in ASQC. Wichita also ranks eighth place in the organization for total membership. District 13 also had 29 percent of the total Aircraft Division membership as of November 1, 1955."

The Membership Committee would also be glad to hear from any other district representatives or any other individual who can give us such happy news.

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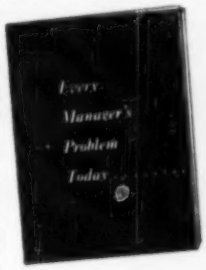

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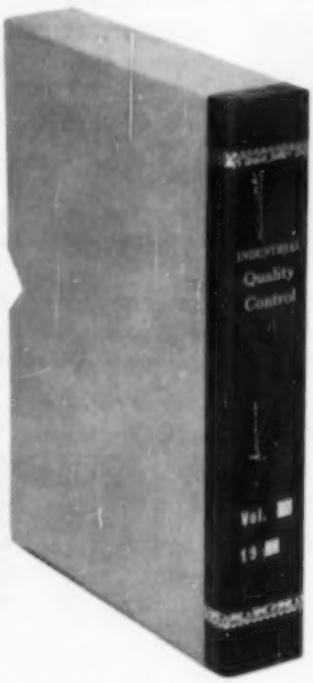

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SIGNIFICANT DIFFERENCES

Curtis Hasty, member of the Birmingham section, is now Assistant to General Works Manager, U. S. Pipe Co., Birmingham, Ala.

Raymond L. Sweeney, vice chairman of the Cincinnati Section, has recently moved to Chicago to accept a new position with Standard X-Ray Co. as Chief Engineer.

Ted H. Crommer, former Delaware section treasurer, has been transferred to take part in Chrysler's guided missile program at Detroit. The section is sorry to see Ted leave and wishes him all of the best in his new assignment with Chrysler.

T. G. Christodoulo, an active member and former treasurer of the Georgia Section, is now with American Cyanamide in Savannah, Ga.

Milwaukee section member, Miles Etzel, formerly chief inspector of the Brown Deer Division of Badger Meter Mfg. Co., Milwaukee, is now with the Evinrude Motor Division of Outboard Marine and Mfg. Co., Milwaukee, Wis., as a methods engineer.

St. Louis section president Joseph Movshin appeared on the ballot for election of officers for the coming year as Midwest Regional Vice President of the American Institute of Industrial Engineers.

Samuel A. Oliva, manager of recording media manufacturing, Dictaphone Corp. and past chairman of the Southern Connecticut section, was a member of the panel at the Bridgeport YMCA Supervisors' Forum. The topic was "Staff function and the supervisor." Sam represented the side of quality control in this panel presentation. The meeting was held on Apr. 12 in the YMCA, Bridgeport, and many of the supervisors in the industries of this area were in attendance.

The Canadian Standards Association Committee on Sampling Procedures held its first meeting on Feb. 27 to discuss ways and means of having good sampling practice introduced into inspection and test specifications of CSA technical committees.

The chairman of the committee is John B. Pringle of the Montreal Section. Other members of ASQC on the committee are Tom S. Czarski, Roger Lessard, and Ben H. Lloyd, Montreal Section; Allin P. Deacon, Hamilton Section; Dr. Brant Bonner, University of Western Ontario Section; and J. Clayton Knapp, Michigan Section. E. Lew Hartman, the other member, is formerly of the Toronto Section.

The committee will review the work done in other countries in reference to the inclusion of sampling methods in descriptive specifications as well as separate sampling instructions, with a view to making available to other CSA committees proper information to include in or append to their technical specifications. The committee will also act in a consultative way with those committees.

The groundwork planned is an educational bulletin and questionnaire to be sent to each CSA committee. These and the results of talks before committees and organizations are to be used as a basis for future planning.

Shirley J. Murphy has been appointed as assistant to the works manager of the Singer Manufacturing Co., Bridgeport, Conn. Mr. Murphy installed the company's first sampling inspection and organized the quality control department in 1951 becoming its first manager. The Southern Connecticut section wishes him well on his new promotion.

Philip Hermann, formerly of Thompson Products, Cleveland, is now supervisor of the Applied mathematics section for the Jones & Laughlin Steel Corp., Pittsburgh. Mr. Hermann is a member of the Pittsburgh section.

Pittsburgh section member D. C. McCune, formerly with The Babcock & Wilcox Co., Tubular Products Div., is now staff statistician for the Jones & Laughlin Steel Corp.

A television series on statistical quality control sponsored by the St. Louis Section and entitled "A new tool for industry" received a fine acceptance from the general public. The section's executive committee were honored with the opportunity to be in on the final program on Feb. 2, and to take part in this fine presentation.

The Indianapolis Section deeply regrets to inform the Society of the recent death of Section President Claude E. Adair. Mr. Adair was an intensely loyal and ambitious person. He performed his duties as president with real leadership putting his whole heart into whatever task he had at hand. He died in an air tragedy at the Pittsburgh Airport on Apr. 1.

The Columbus Section deeply regrets to announce the death of James Winfield, Superintendent of Quality Standard Department, Ternstedt Division, General Motors Corp. and long time member of our Society. Mr. Winfield passed away Feb. 24 in Malibu, Calif.

For Introductory Courses . . . .
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For An In-Plant Training Manual . . . .

—o—

A BASIC TRAINING MANUAL
ON
STATISTICAL QUALITY CONTROL*

Published by
St. Louis Section, ASQC
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St. Louis, 5, Mo.

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Management's Corner

J. M. JURAN, *Editor*

Progress for QC Engineers—Horizontal or Vertical?

OUR modern industrial companies require numerous specialized activities (and thus numerous specialists) to perform the mission of the enterprise. The variety of these specialists is very great—industrial engineers, cost accountants, personnel assistants, metallurgists, tax attorneys, and many others, including quality control engineers. In the larger companies these specialists are brought together into specialized departments for greater effectiveness. The result is the quality control department, cost accounting department, etc.

The direction of progress (or "line of promotion") of the specialist is an important, unsolved industrial problem. It is important because there are so many specialists and because they are so vital to the health of the enterprise. It is unsolved mainly because we are dealing with widely different forms of human satisfaction.

The Available Rewards

The enterprise has the opportunity to give rewards to the specialist in several distinctive ways.

First there are rewards inherent in the specialized job itself: a pleasant friendly workshop; challenging problems; an adequate budget for tools, instruments and equipment; a well-chosen library; stimulating leadership; response to the recommendations the specialist prepares.

In addition, there is a list of rewards given to the specialist as a person, as distinguished from those which can be given to specialists as a species. These rewards include promotion in rank, increase in salary, appointment to committees, etc.

There are additional rewards which relate to opportunity for progress in the profession. These include attendance at meetings of professional societies; presentation and publication of papers; membership on society committees, etc. To the profession-oriented specialist, these things are vital. They are the basis for professional achievement and recognition. Without them there is only professional oblivion.

Approaching the Cross-roads

In the small company the one-man specialist department soon finds himself faced with the question "Where do I go from here?" He has already become the top company authority in his specialty. His alternatives now include:

(1) Let nature take its course. Just stay on this job and do it as well as he knows how. In time something will happen.

(2) Find a bigger industrial base. Look for a job in the same specialty but with a larger enterprise. This opens up a wider opportunity for all forms of satisfaction.

(3) Find another type of institution to be the base. Look for a new way of utilizing the specialized know-how, as a researcher, as a teacher, as a writer, as an employee in a consulting company.

(4) Forget the base. Become a one-man consultant in the specialty. (One day Management's Corner may discuss this.)

(5) Strive for promotion. This means, in a small company, (and ultimately in the large company) *changing professions* from technical specialist to administrator.

(6) Launch a new enterprise. This is just a more precipitate form of either (4) or (5).

It is seen that, in the long range, the choice must be made between staying in the specialized profession or getting out of it.

In the large company the same basic choices are there. However, there is one intermediate factor which delays the need for a decision. That factor is the existence of the large specialized department, and the opportunity it provides for verticle *promotion within the specialty*. Through promotion within the specialty all forms of satisfaction can be broadened, without leaving the profession, much.

However, the specialist often overlooks the fact that by the time he has become head of a large specialized department, he has shed many of his professional skills. Year after year he has spent less and less time with his books, test tubes and slide rule. More and more his time has been occupied with hiring and directing assistants, with budgets, with conferences, with other incidentals of managerial activity, with getting results through the efforts of other people.

In the large company the problem of "where do I go from here" reaches its dramatic fulfillment when the head of a specialized department has reached the top of the grade. Moreover, by asking the question he implies a reluctance to spend the rest of his days on his present assignment. It implies further that there is an unspent drive looking for a direction to go.

The Company's View

It is interesting to study the contrasting views of the company and the specialist when this fork in the road is reached. Each has an array of logical contention, but starting from different premises.

The company points out that all three forms of reward are limited.

Pay and amenities cannot go far beyond the market price for comparable jobs without creating, for the company, new problems fully as severe as those solved. Status or rank likewise has limits, since there is a "market" status for other functions no less important than quality control.

Job conditions and interest can be modified to a degree, but again there is an elastic limit.

Participation in the work of the profession is a good thing, but again there must be a limit. There are enough meetings and other professional society activities to occupy the full time of some men were there no limits imposed. These things can easily be magnified into annoyances when persistent profession-oriented specialists encounter impatient executives. Attendance at conventions means absence from the job. Writing of papers means reviews and clearances. Service on committees can be time consuming. All this is in contrast to the absence of such activities on the part of promotion oriented-men.

The Specialist's View

For the man who is thoroughly profession-oriented, it is the profession which is permanent; the company may be only a temporary habitat.

From the view of the profession-oriented specialists, there are nu-

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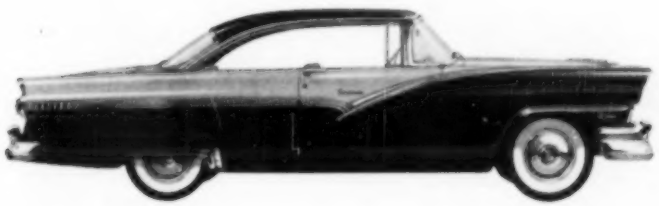

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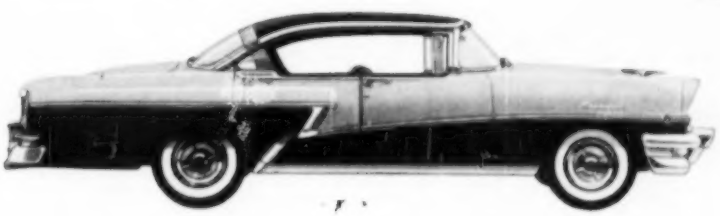

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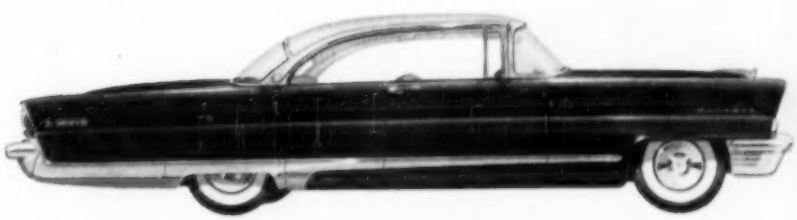

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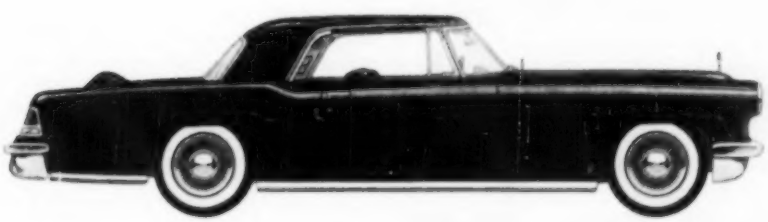

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Laboratory technicians use a Kelvin Bridge to measure to the nearest microhm electrical resistance across the connector joints, and compare readings with equal lengths of uninterrupted cable.

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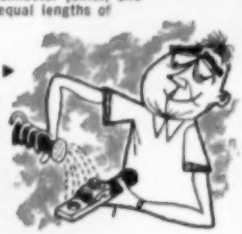

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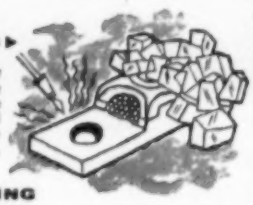

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Clamp-type and split-bolt connectors are subjected to torque tests. Connectors are tightened with a turning force sufficient to cause failure of the hardware or of the connector itself. Maximum connector strength measurements as well as valuable design information is secured.

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merous injustices in industrial life. The administrator commands higher pay and greater prestige than does the professional. Many companies have failed to grasp the inspirational force of professionalism, and through this failure, tend to interpret loyalty to the profession as a form of disloyalty to the company. (The promotion-oriented executive takes company papers home at night, not professional society papers.)

A touchy subject is "authority". The administrator has clear authority of position; the professional must rely on the authority of knowledge and of personality. Actually, these are adequate to secure action, but the professional often doesn't know this, and longs for the authority of rank which is denied to him.

No less touchy is the unbalance which can develop between prestige in the profession and prestige in the company. There are numerous occasions in a professional society function where the young quality control engineer sits with the dignitaries at the head table while his manager sits with other unknowns on the floor. But the next morning, the engineer is back at his desk in the big room, while the manager is back in his private office.

What Solution?

The search for a solution is like the search for quality of product—we must first agree on the specification. In the experience of this department (which gets around rather widely), the most troubled professionals are those who are already at the fork in the road, but who as yet have failed to realize that there is a choice to be made. Before this realization has dawned, the internal troubles of the professional can easily break out into industrial misdemeanors. But with an understanding of the situation, a positive, constructive program becomes possible.

Each troubled specialist must occasionally ask himself "What do I want to be doing ten or 20 years hence." No matter how vague the answer, it still provides some directional aid, since individual actions can then be considered as to whether they lead generally toward or away from this goal. But even more than this, there is a wholesome self-discipline in addressing oneself to such a question. The resultant search for truth clears the mind of much fog, and makes it easier to direct one's energies toward achieving results rather than toward embellishing one's troubles.

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New Dimensional Standards Established for Gage Blocks

First major improvement in gage block accuracies in 40 years meets realities of today's precision tolerances . . . overcomes inadequacies of finest blocks previously available

By RAY GIERLICH, Gage Division The DoAll Company, Des Plaines, Ill.

Here is What Has Been Done

- **New laboratory gage block Grade AAA established with accuracy of plus or minus one-millionth inch per inch of length—the finest gage blocks ever manufactured commercially.**
- **Grade AA blocks (±.000002") reduced in price as much as 70%, permitting wide usage for routine inspection work.**
- **New accuracy of plus .000004", minus .000002" established for Grade A blocks, with prices reduced below that of Grade B. (National Bureau of Standards tolerance for Grade A blocks is ±.000004" per inch. The new tolerance of two-millionths (.000002") on the minus side affords a more accurate block and provides two-millionths cushion for wear.)**
- **Grade B sets (±.000008") discontinued on the basis of their inadequacy for close tolerance measurement.**
- **New optical surface finish (guaranteed 0 to 0.09 RMS microinches) established for all blocks, providing superior accuracy and wear life.**
- **Every block is accompanied by a Certified Inspection Report stating deviation from nominal size.**

COMPLETELY NEW standards for gage blocks have been established by The DoALL Company after a comprehensive appraisal of modern measurement needs. They represent the first basic improvement in gage block accuracies since World War I, when .001" was a high degree of precision.

Consider .0001", a common tolerance today. The checking gage must be accurate to .00001"—equal to or better than the accuracy of many gage blocks in common use! For example, a new one-inch gage block is actually acceptable as "B" Grade if accurate to ±.000011" including observational error. A two-inch block could have a permissible error amounting to 20% of the tenth (.0001") tolerance. The error in a stack of such blocks would be prohibitive.

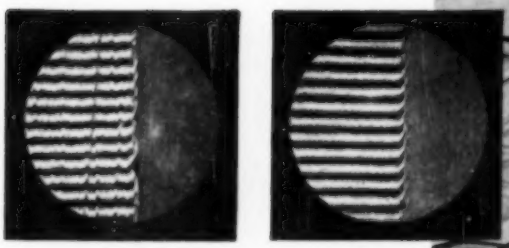
When tolerances of 75, 50 and even 25 millionths are specified, the need for better gages is instantly apparent.

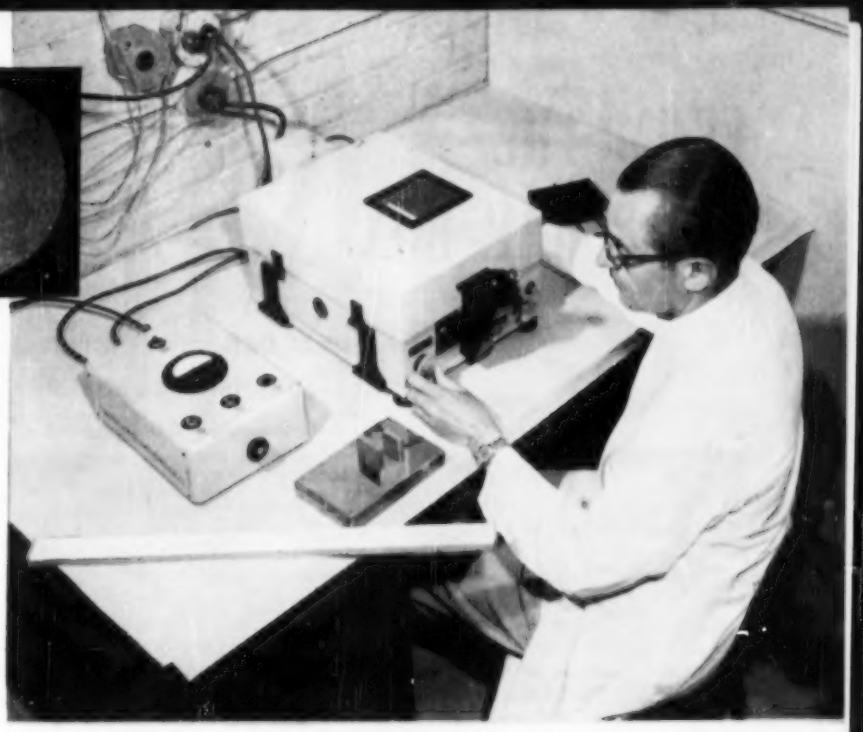
As summarized at the left, DoALL has discontinued manufacture of Grade B blocks and has standardized on the grades listed in the following table.

New Standards for DoALL Gage Blocks

Grade	Tolerance per Inch of Length	Flatness	Parallelism	Surface Finish Microinches RMS
"AAA"	+.000001 −.000001	.000001	.000001	0.09
"AA"	+.000002 −.000002	.000002	.000002	0.09
"A"	+.000004 −.000002	.000004	.000004	0.09

Left—New DoALL Gage Block Sets are available in AAA, AA and A grades in 20 individual square block sets and 22 rectangular block sets ranging in sizes from 5 to 121 pieces. This includes two rectangular sets in the metric system. New plastic cases are compact, easy to clean and exceptionally durable and attractive. Wear blocks are available in sets in .050" and .100" sizes. A complete line of accessories makes possible assembly of fixed and indicating gages for every conceivable requirement.





Micro-interferograms of Block Edges

Above Right—DoALL Block Edges are "burr-proofed"* *after* final lapping by blending the gaging surfaces into a parabolic corner break that leaves no trace of a sharp edge. This exclusive process eliminates formation of edge burrs that cause wear and destroy accuracy.

Above Left—Sharp, ragged edge typical of blocks on which a corner radius is ground *before* final lapping. In use, damaging edge burrs are commonly formed.

Right—The author inspects blocks for dimensional accuracy with Zeiss Opton Interferometer in DoALL air-conditioned Gage Laboratory.

To provide infinitesimally accurate gaging, all blocks are now accompanied by a Certified Inspection Report stating deviation from nominal size.

Optical Surface Finish

Precise calibration of DoALL Gage Blocks to these new demanding standards would be impossible without another new achievement in gage block manufacture—optical surface finish of 0 to 0.09 RMS. For comparison, a gage block with a 1.0 RMS finish cannot be measured accurately to closer than two-millionths of an inch. The new finish also eliminates the severe, wear-producing abrading action encountered when rougher blocks are wrung together, thereby greatly extending the useful life of the blocks.

New Fractional and Tenth Blocks

To further meet modern measurement requirements, three major DoALL blocks have been enlarged to increase their versatility and speed gaging. The previous 118 piece set has been increased to 121 pieces by addition of 5/64", 7/64" and 3/32" blocks. The former 83 piece set has been enlarged to 86 by addition of .100025", .100050" and .100075" blocks, while Set No. 37 now becomes Set No. 38 with the addition of a .100050" block for half tenth measurement.

Gage Maintenance Manual

Handling and wear eventually take their toll of even the finest gage blocks. Therefore, periodic inspection and calibration is required. To help gage users save time and money, DoALL has developed the first practical guide to gage block inspection in the user's own plant. Entitled "Shop Inspection and Calibration of Gage Blocks", it describes the equipment and methods required for simple inspection for flatness and wear as well as for precision calibration of blocks. Copies are available upon request.

* * *

DoALL now offers industry the most accurately made and accurately calibrated gage blocks in the world. They provide finer, faster, lower-cost dimensional quality control than has ever before been available.

Magnified Finishes

An ordinary microscope reveals differences in gage block finish.

Left—DoALL Block finish—guaranteed 0 to 0.09 RMS microinches. This block can be accurately calibrated by interferometry to tenths of a millionth of an inch because fringe lines are sharply defined. This fringe pattern can be seen simply by using an optical flat and monolight.

Right—Finish typical of many blocks in use today. This block cannot possibly be calibrated to tenths of a millionth because fringe lines are fuzzy and difficult to interpret.

Fringe lines formed by optical finish

Fringe lines formed by rougher finish

FOR COMPLETE INFORMATION—

Call your local DoALL Service Store or write The DoALL Company, Des Plaines, Illinois.

LITERATURE FREE ON REQUEST—

Call or write for a copy of the new DoALL Gage Block Catalog, listing all sets and accessories.

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FROM THE SCRAP BOX

MASON E. WESCOTT, *Editor*

Defects Per Unit of Difficulty as a Basis for Quality Rating

BERNARD EISENBERG

Emerson Radio & Phonograph Corp.

Where the same type of unit is being produced on different production lines, we may compare line quality by means of defects per unit.

However, where several production lines in the same or different plants are manufacturing a variety of types of electronic equipment, defects per unit as a measure used to compare the performance of one line with that of another becomes meaningless since the difficulty of constructing one unit of one type of equipment may be considerably different from that of another. Although defects per 1000 solder connections can be used for comparison purposes, this doesn't account for the space factor involved in the soldering and wiring operations. The same number of defects per 1000 solder connections for two different units would not necessarily indicate equal quality rating since one unit may be very small in volume compared to the other unit. A two socket 4 x 4 x 4 inch chassis for example which was being produced with a defect rate of one defect per unit cannot necessarily be said to represent better workmanship than a six socket 2 x 2 x 2 inch volume chassis which was being produced with two defects per unit since the latter may be 24 times as difficult to construct as the former, in which case its quality rating should be considered as being better.

For purposes of quality rating comparison between different types of electronic equipment, it seems desirable to use as a common measure, *defects per unit of difficulty*. The term "unit of difficulty" may be defined as a fixed number of solder and wire connections per unit of chassis volume. We shall say that a piece of electronic equipment has one unit of difficulty when it contains one solder connection per one cubic inch of chassis volume. The assumption is made that this unit is constant between different types of electronic equipment, i.e. it is just as possible to perform good workmanship in a unit of difficulty of one type of electronic equipment as it is in any other type. Having standardized the opportunity for defects to occur by dividing each piece of electronic equipment into uniform units of difficulty, we may proceed to compare the quality rating of one type of equipment to that of another.

The number of solder connections* in a unit volume, is tentatively chosen as the fundamental measure of comparison. The greater the number of solder connections, the more difficult will the construction be, and the greater the volume, the easier will the unit be to construct. Since the number of solder connections is dependent to some extent on the number of wires, either the number of solder connections, the number of wires, or a function of either or both may be used in the definition of unit of difficulty instead of the number of solder connections alone.

The following is an example of how this measure may be used. Suppose we wish to compare the quality rating of three pieces of electronic equipment A, B, and C. Let's say that ten defects per unit, 20 defects per unit, and 30 defects per unit were found in A, B, and C respectively, averaged out over a month. Suppose that A has five solder connections per unit volume (or five units of difficulty), B has eight solder connections per unit volume (or eight units of difficulty), and C has 20 solder connections per unit volume (or 20 units of difficulty). Then the defect rate for A is

$$\frac{\text{10 defects per unit}}{\text{5 units of difficulty per unit}} = \text{2 defects per units of difficulty.}$$

*One solder connection may be defined as a point at which one or more wires are soldered together.

The defect rate for B is

$$\frac{\text{20 defects per unit}}{\text{8 units of difficulty per unit}} = \text{2.5 defects per unit of difficulty.}$$

and the defect rate for C is

$$\frac{\text{30 defects per unit}}{\text{20 units of difficulty per unit}} = \text{1.5 defects per unit of difficulty.}$$

Although unit C has the largest number of defects per unit of the three units, its difficulty of construction is much greater than that of A or B. Upon evaluating the defect rates in terms of defects per unit of difficulty it can therefore be concluded that the quality rating of unit C was better than that of either A or B.

Dear Mr. Wescott:

The acceptance by industry of Statistical Quality Control has always been met with varying degrees of resistance. Perhaps we ourselves are guilty of creating some needless obstacles to our own progress.

My personal complaint has always been the emphasis we place on the word "defects." A critical defect, a major defect, a minor defect!

One of the basic aims of Statistical Quality Control is the improvement of manufacturing processes and products through defect prevention. We are attempting to eliminate, or at least minimize, the occurrence of defects. Why then, do many of us in Quality Control—engineers, supervisors and lecturers alike—when dicussing a component or a product refer to a particular diameter as being a major *defect*; to a hole size as being a critical *defect*. Aren't we really speaking of *characteristics*!

The word "defects" stimulates negative thinking. As a result, those

to whom we are attempting to sell our ideas are often reluctant to cooperate in implementing our programs.

Although we should be the first to admit that characteristics vary, we must not allow our thinking to reflect any implication that we are working with defects. We are interested in controlling the quality of characteristics.

Unless we are careful, others may soon exploit the idea that we have unthinkingly suggested—that we are concerned with *defect control* rather than *quality control*.

Very truly yours,
G. H. Overbagh
International Business Machine Corp.
Neighborhood Road
Kingston, New York

Editorial Note: The following is part of the letter acknowledging Mr. Overbagh's comments:

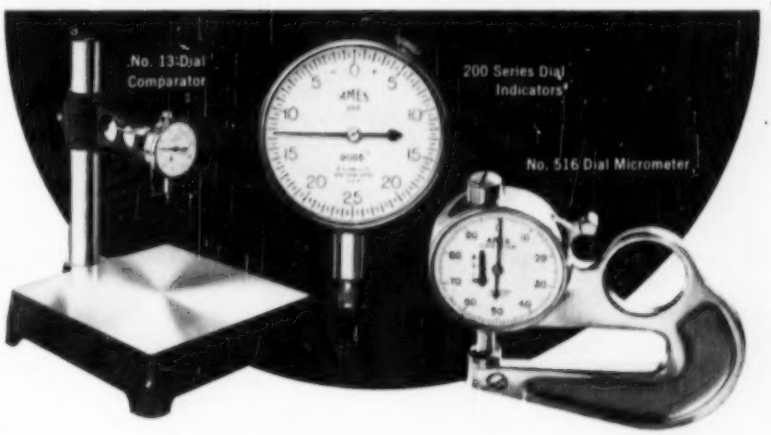
"I think you have a good point, but I am afraid the practice has already become too deeply embedded in the literature and language of the field to have much hope of it ever being changed along the lines of your suggestion. It is something like the designation of the square root of negative numbers as "imaginary numbers." Such numbers are no more *imaginary* than the ordinary positive integers. However, before recognition of this fact could take hold in the field of Mathematics, the designation as imaginaries had become so thoroughly entrenched in the literature of Mathematics that changing it would be impossible."

"While we are on the subject, I confess that in my early contacts with the SQC field, I used to wonder why the variable p was defined to be the percent *defective* rather than the percent *good*. Here again, we are tending to look at the negative side of the picture rather than the positive and here again, tradition has by this time so thoroughly crystallized that no arguments, however tenable, are ever likely to succeed in changing the existing practice."

Mason E. Wescott
Chairman, Editorial Board

You need never worry about losing your shirt if you always keep the sleeves rolled up.

AMES



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Bibliography

JOSEPH MOVSHIN, *Editor*

Assisted by the Editorial Committee, St. Louis Section, ASQC

APPLICATION—

METALLURGICAL INDUSTRY

COMMON SENSE IN QUALITY CONTROL, by Henry C. Ahl
(Modern Castings—v. 29, Jan., 1956, p. 57-61)

This article discusses the program for quality control in small bronze foundries. It is necessary to key the program to the needs and budgets of the organization. The article contains suggestions and examples of methods of controlling casting quality on limited budgets.

APPLICATION— TEXTILE INDUSTRY

TESTS FOR DRAWING AND ROVING, by Norbert L. Enrick (Institute of Textile Technology)
(Modern Textiles Magazine—v. 37, n. 3, Mar., 1956, p. 32-40)

Continuing the series on quality control mill test procedures, this article discusses the following tests:

- Drawing Spoon and Trumpet Check
- Roving Tension and Twists Check
- Roving (and Spinning) Horizontal Traverse Check

As was done in past articles, the tests are described in detail, forms to be used for recording the information, frequency of testing and evaluation of the data is described. Nomograph for analysis of the roving twist test is also given.

ENGINEERING & EXPERIMENTS

HOW TO USE STATISTICAL QUALITY CONTROL FOR MATERIALS SELECTION, by D. Peckner, Westinghouse Electric Corp.
(Materials and Methods—v. 43, n. 4, Apr., 1956, p. 120-122)

Through the use of methods described in this article, it is possible to set up specification limits, check material performance over a period of time, and accurately check a supplier's claims concerning his product. Specifically, the confidence envelope is used. It is described in some detail together with an outline of its construction. Factors for multiplying the estimated standard deviations to obtain confidence limits for average standard deviations are given. A short discussion of probability paper is given.

A TRIAD FOR DESIGN RELIABILITY, by F. E. Dreste
(Electronic Equipment, Jan., 1956)

This article considers the problem of reliability from the standpoint of the design requirement. Such consideration of course must start from the reliability of a known component. Operational parts tolerances and a statistical consideration of variability in the design must be considered. Model testing can provide the information for the statistical analysis.

Selected references in the Bibliography of *Industrial Quality Control* are obtained from the following sources:

The International Statistical Institute, *International Journal of Abstracts on Statistical Methods in Industry.*

MANAGEMENT & PERSONNEL, GENERAL

SELLING MANAGEMENT A QUALITY CONTROL PROGRAM, by Ray F. Engelgau, (Mueller Brass Company, Port Huron, Michigan,) and Harmon S. Bayer, (Quality Control Consultant, Detroit, Michigan)
(Tooling and Production—v. XXII, n. 1, Apr., 1956, p. 78-81)

In order to sell a quality control program, it is necessary to sell yourself, your boss and top management. It is also necessary to point out to top management that certain personnel are needed. That a quality control program required a department and a selling program to middle and lower management. It is then necessary to use a "pilot job" to graphically evaluate the benefits and simplicity of Statistical Quality Control.

INDUSTRIAL MANAGEMENT

COMPARISON OF ALL-DAY TIME STUDY WITH WORK SAMPLING BY USE OF ANALYSIS OF VARIANCE, by L. J. Cote, Statistical Laboratory, Purdue University and B. J. Scott, Lt., U.S.N.
(The Journal of Industrial Engineering, v. VII, n. 1, Jan.-Feb., 1956, p. 31-34)

Lowest Priced Fine Quality Springs Money Can Buy
PROMPT CAREFUL SERVICE
AMERICAN COIL SPRING COMPANY
SEND US YOUR INQUIRIES
It's Always Springtime at our House

Controlled - - - Quality - - -

Proper Design - - Metallurgical Exactness - - Consumer Satisfaction

SQC on the job

These men making telephone equipment at Western Electric can't help keeping an eye on quality... and costs. For here, as you see, we've brought SQC right to the point of work.

We've found this practice pays off for everyone. For ourselves... because it helps keep quality up and scrap losses down. For employees... because it helps boost their acceptable production and earnings. It pays off for telephone users, too, since it helps give them good, dependable telephone service at low cost.

Western Electric

MANUFACTURING AND SUPPLY UNIT OF THE BELL SYSTEM

Nothing beats experience

Dozens of rival zippers have appeared on the market since Talon, Inc., invented the zipper back in the dark days of the hook and eye. But none has achieved the over-all superiority or the reputation for quality of the Talon zipper—which has had zipping experience in nearly *five billion* pieces of merchandise!

To maintain this unrivalled leadership, Talon, Inc. adheres to the highest quality standards of the industry.

Talon

THE QUALITY ZIPPER

TALON, INC., READVILLE, PA. • IN MEXICO CIERRE RELAMPAGO S. A. DE C. V. IN CANADA, LIGHTNING FASTENER COMPANY, LIMITED

In this study, all-day time study was compared with work sampling or ratio delay. Analysis of variance is the basic technique used. Questions to be studied include the relative accuracy of each sampling method and the time required to obtain this accuracy. It was desired to check the assumptions used in standard time studies; namely that the process is stable and daily variability is small, that one or two or a few machines are typical of all machines or work stations and that variability among different operators or crews is negligible or can be assumed to be negligible by rating. The statistical consideration and methods of establishing and developing the data are discussed in detail. The conclusion basically reached is that the work sampling plan is superior to all-day time study.

MISCELLANEOUS

HOW TO CALIBRATE YOUR GAGE-BLOCKS, by Frederick O. Hutchinson, The DoALL Company, Des Plaines, Illinois
(Machinery, v. 62, n. 7—Mar., 1956, p. 160-166)

This article describes the mechanical technique for inspecting gage-blocks. The use of monochromatic light, optical flats and cleaning equipment is described. The basic measuring equipment is also indicated.

PRECISION TO A FRACTION OF A LIGHT WAVE, by M. S. Hoskins, Metrologist, Sheffield Corp.
Machinery, v. 62, n. 7—Mar., 1956, p. 190-193)

This article describes "interferometry". This is the measurement and standardization of measurement by light wave. Some of the instruments used and the theory are also presented.

STATISTICS

THE MOMENTS OF THE SAMPLE MEDIAN, by John T. Chu and Harold Hotelling
(The Annals of Mathematical Statistics, v. 26, n. 4—Dec., 1955, p. 593)

AN EMPIRICAL DISTRIBUTION FUNCTION FOR SAMPLING WITH INCOMPLETE INFORMATION, by Miriam Ayer, H. D. Brunk, G. M. Ewing, W. T. Reid and Edward Silverman
(The Annals of Mathematical Statistics, v. 26, n. 4—Dec., 1955, p. 641)

NEW!

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10X to 40X

Handy 'scopes spot-check production, speed small parts work

• Actual size as shown here ... compact, handy

• Shows natural right-side-up views... easier for inexperienced users... a big help in precision assembly!

Just grab this dependable inspection aid for on-the-spot checks of work and materials in any phase of production. Available with folding tripod or sturdy microscope stand, for detailed study and for small-parts assembly. You can even build it right into production machinery!

Upright images are sharp and detailed to the very edge of the extremely wide field of view. Long working distance makes it easy to manipulate specimens ... gives operators plenty of room for precision assembly and repairs. (Also available as straight tube for applications where upright image is not required.)

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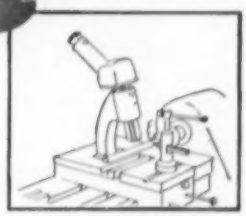
ON-THE-JOB DEMONSTRATION!
Find out how this inexpensive production tool can lower your manufacturing costs. WRITE, WIRE or PHONE today for free demonstrations and Data Bulletin D1052. Bausch & Lomb Optical Co., 79505 St. Paul St., Rochester 2, N. Y. (Phone: LOcust 3000).

Use it in tripod...

in microscope stand...



... or even built into machinery!

BAUSCH & LOMB
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AMERICA'S ONLY COMPLETE OPTICAL SOURCE
... FROM GLASS TO FINISHED PRODUCT

ROTATION SAMPLING, by Albert R. Eckler
(The Annals of Mathematical Statistics, v. 25, n. 4—Dec., 1955, p. 664)

MULTI-LEVEL CONTINUOUS SAMPLING PLANS, by Gerald J. Lieberman and Herbert Solomon
(The Annals of Mathematical Statistics, v. 26 n. 4—Dec., 1955, p. 686)

ON THE RATIO OF VARIANCES IN THE MIXED INCOMPLETE BLOCK MODEL, by W. A. Thompson, Jr.
(The Annals of Mathematical Statistics, v. 26, n. 4—Dec., 1955, p. 721)

OPERATIONS RESEARCH

BETTER MANAGEMENT — MANAGEMENT, INDUSTRIAL ENGINEERING, LINEAR PROGRAMMING, by John J. Wilkinson, Methods Engineering Council, Pittsburgh, Pennsylvania

(The Journal of Industrial Engineering, v. VII, n. 1, Jan.—Feb., 1956, p. 11-23)

In this article linear programming is represented as a management tool which can supplement industrial engineering to provide better overall management of an activity. Linear programming is defined and applications are indicated. The application of linear programming is broken down with a discussion of the following areas:

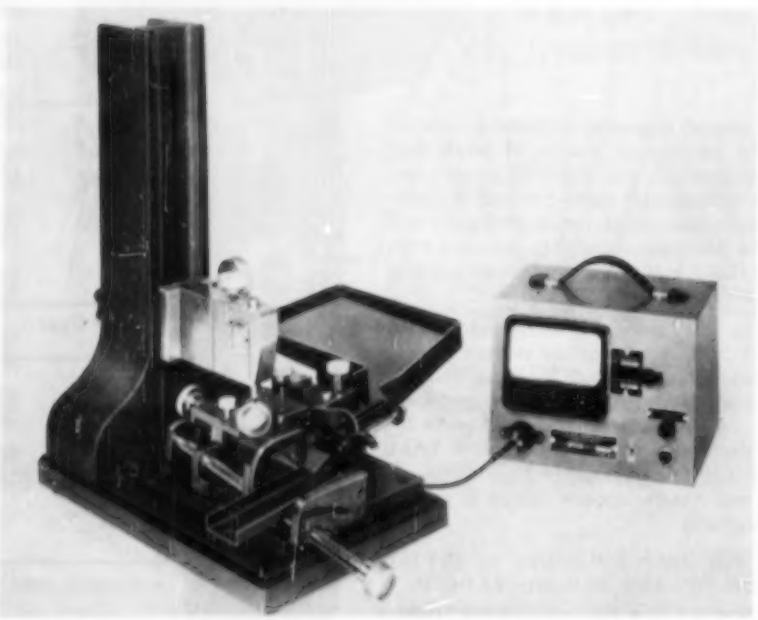
- What you need to know about the problem.
- How the problem information is organized
- Linear programming methods.

The article then goes on to describe in some detail the actual application of linear programming techniques and the solution of many problems.

What's New?

ROY A. WYLIE, *Editor*

When inquiring about "What's New?" items, please mention INDUSTRIAL QUALITY CONTROL



Cleveland Instrument Co., Cleveland, Ohio, has announced a new ball-bearing measurement attachment for use with the company's Micro-Ac electronic comparator. The new attachment gages ball bearings of from one millimeter up to 1½ inch diameter to an accuracy of ½ millionth of an inch. In addition to gaging ball diameter, the equipment can be used for random sphericity gaging. Essentially, the attachment is a V-shaped block mounted at a slight angle to permit the ball to roll into a chute after completion of the gaging operation. A manually operated lever moves the ball into the gaging position under the Micro-Ac gage head. Since the ball is untouched by hand, there is no possibility of heat transfer to cause inaccuracies nor is there any "etching" of the ball from acidhand perspiration. The gage head contact tip pressure is four ounces. A precision-lapped compound screw provides for fine adjustment of the head, and a positive stop gives over-travel protection. Movement of the contact tip displaces a linear-voltage, differential transformer. This produces a signal which is directly proportional to the amount of displacement of the contact tip from its zero position. This signal goes to the dual-sensitivity amplifier, the output of which is fed to the amplifier meter (or recorder) to show both the amount and direction of displacement either side of the zero position. The two amplifier sensitivities give direct meter readings of 0.000001 or 0.0000005 inch. Meters calibrated in microns or other units are available on special order.

★ ★ ★

Brush Electronics Co., 3405 Perkins Ave., Cleveland 14, Ohio, have announced a new portable electronic instrument for checking metals without laboratory analysis. Called the "Metal Monitor" it can identify ferrous and non-ferrous metals by comparative testing with known samples and can be used to sort mixed metals of unknown character into homogenous groups for further testing. It can also be used to check stock, parts in process or finished products for many characteristics other than chemical composition, such as hardness, heat treatment, metallurgical structure, uniformity, plating thickness and plating adhesion. The Metal Monitor is sensitive to differences between two pieces of steel as little

as one point of carbon. Operation of the device is based on a principle of the thermocouple effect: the junction of two dissimilar metals produces an electromotive force. In operation, an electrode (with a self-heating element) is placed in contact with the metal to be tested. The voltage generated by this contact is amplified and transmitted to a meter on the Metal Monitor. The reading is then compared to readings obtained from samples whose compositions and metallurgical characteristics are known. The device is easy to operate and requires no special or technical education on the part of the operator. It weighs only 21 pounds and can be moved to the job. Since the Metal Monitor is non-destructive it can be used on finished parts and assemblies and only a very small area of contact is required on the piece being tested.

Also included in their line of electronic instruments is a new Deviation Test Bridge Model BL-1506. The instrument quickly presents a comparison against a standard impedance, indicating both percentage impedance and phase angle deviation in radians on a 6-inch illuminated scale. Interchangeable calibrated scales are provided for the ranges −1.5 to +1.5 percent, −7 to +8 percent, −25 to +35 percent impedance deviation and −0.015 to +0.015, −0.07 to +0.07, −0.25 to +0.25 phase angle deviation radians. The new deviation Test Bridge has a 100 kc bridge frequency for the test ranges 10 to 50,000 ohms resistance, 25 mmfd to 0.1 mfd capacitance, and 20 microhenry to 80 millihenrys inductance. For automatic inspection the meter can accommodate 4000 units per hour. The Knee Operated Test Jig Accessory BL-3901 will greatly facilitate manual inspection procedures.

★ ★ ★

An adjustable flush pin gage which can be set to a wide range of sizes for varying production dimensions was introduced recently by **Size Control Co.**, 2500 West Washington Blvd., Chicago 12, Ill. The new gage may be set to measure the depth of a wide range of machined holes within an accuracy of four decimal places. In effect, the gage becomes many gages, adaptable immediately to new production dimensions, eliminating the necessity for designing, ordering and waiting for new gages each time specifications are changed. It may be adjusted simply by loosening a locking screw, turning the adjustable contacts to the proper dimension, and re-locking the screw. In addition to outright savings on gage purchases, the user achieves additional economies since he need not interrupt production schedules to wait for a new gage each time there is a design change.

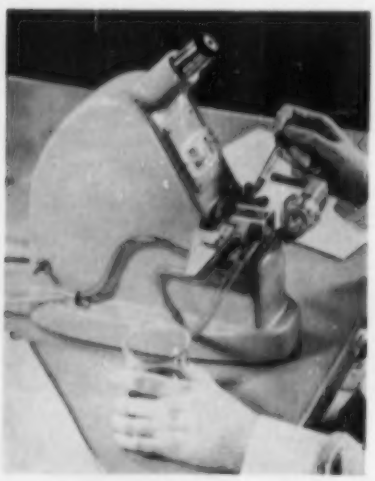
★ ★ ★

Micrometrical Manufacturing Co., 345 South Main Street, Ann Arbor, Mich., announces the Profilometer Type LJ Tracer for measuring surface roughness. This new Tracer will measure more than 85 percent of all the varied surfaces produced by industry, and measures all surfaces produced in many plants. It can be operated by Mototrace or by hand and can be used with any Profilometer Amplimeter and Mototrace.

It's New!
A dependable, LOW COST . . .
Motorized Brinell Hardness Tester by
Steel City Testing Machines, Inc.
● Positive accuracy
● Finger-tip operation
● ¾" stroke
● For shop or laboratory
Now even the smallest shop can afford a dependable and versatile Brinell Hardness Tester. Priced exceptionally low, Model L is a motorized hydraulic machine with which even an inexperienced operator can make tests in strict conformance to A.S.T.M. Standards.
Engineered by Steel City, leader in the field since 1914, the new tester is designed for years of maintenance-free operation. The ¾" stroke permits successive tests without anvil readjustment. Load is applied by finger-tip pressure on operating handle.
Write for full particulars today and name of nearest sales representative—conveniently located in your area.
MODEL L
Vert. opening—9"
Throat depth—6"
Bench space—9" x 25"
Manufacturers of machines for testing physical properties of metals, including:
Steel City Testing Machines Inc.
8803 Lyndon Ave. Detroit 38, Mich.
Brinell Hardness
Ductility
Tensile
Compression
Transverse
Hydrostatic
Proving Instruments
Flex Tester
. . . and Special Testing Machines.

The Tracer point is placed at the end of the projecting beam and there are three interchangeable Skidmounts to support the Tracer on the work surfaces. The Type FP Skidmount has a small-diameter nose, with a single skid directly back of the Tracer point, and is used for mechanical tracing with a Mototrace. ID's as small as ¼ inches, OD's as small as ⅛ inches, flats and tapers can be measured with the combination. Types FL and FM Skidmounts have two skids and are used for manual operation with the tracer held by a plastic clip or attached to a Stiffarm or Extension Arm. They may also be used for Mototrace operation. The Type FL is used on ID's from ½ inches to flat; and the Type FM is used on OD's from ⅜ inches to flat. Both may be used on gear teeth as small as 10 D.P.

* * *



Bausch & Lomb Optical Co., Rochester, N. Y., have introduced the Abbe-3L Refractometer. In one minute the operator can load, light and look into the instrument to obtain the refractive index of liquids, dissolved solids and some opaque solids. It is particularly useful as a quality control tool in the food, chemical and petroleum industries, for production line applications where it can be operated by non-technical workers. Loading the refractometer has been simplified by mounting the prism assembly in front of the operator within easy reach and in a horizontal position to reduce spillage. The sample is lighted with a built-on illuminator which swings into position. Lamps can be easily changed and are the readily-available flashlight type. Readings are taken with a single eyepiece, from a sitting position. Numbers are easy to read because of an internal illumination system. Refractive index range is 1.30 to 1.71; solids scale reads zero percent to 85 percent. The instrument will require little field servicing. Users can make complete calibration adjustments with an Allen wrench by inserting the wrench through an opening in the instrument body and turning it until the reading corresponds with that of a glass test-piece. Prisms can also be changed by the user. Price of the Abbe-3L Refractometer is $695.

* * *

Baird Associates, Inc., 33 University Road, Cambridge, Mass., announce the new Transistor Test Set Model GP. The test set provides rapid, accurate measurement of transistor characteristics at any frequency from 100 cps to 1 megacycle. It permits measurement of NPN and PNP junction, surface-barrier and point-contact transistors in grounded base and grounded-emitter circuits. Measurements of hybrid coefficients, T-network coefficients, collector saturation current, collector capacitance, alpha and beta cutoff, voltage feedback ratio, open circuit resistances, and channel effect voltage can be accurately made with Model GP. Panel design of the GP permits rapid adjustment of test conditions. A large, polarity-indicating meter facilitates fast readings. The Transistor Test Set employs unusual circuitry and long-life batteries to reduce measurement errors. Bias conditions are variable over wide ranges to facilitate testing of the circuits under various conditions.

* * *

Scale Specialties & Systems, Inc., P.O. Box 57, Roseland, N. J., have developed the Curvomatic attachment to be installed on the side of their Datamatic Weight Calculator. The Curvomatic attachment simplifies the analysis of weight data produced by the Datamatic. In a matter of minutes clerical and quality control people can produce a daily weight frequency curve and easily calculate standard deviations. Weight range can be divided into a total of 15 cells and each cell is supplied with an electric counter which registers and integrates a single digit each time a weight falls within a given cell. At the end of the day or any other period of time, the counters may be read and a frequency curve obtained. The Curvomatic attachment to the Datamatic weight calculator should extend the usefulness of this tool for weight control at the filler unit. For laboratory use, when a control tool, such as the Datamatic is not required, the Curvomatic data collector is available as a separate unit.

* * *

A new Transconductance Analyzer and Circuit Designer has been developed by the **New London Instrument Co.**, New London, Conn., for quality control, design engineering and production test use. The Model 901A measures transconductance and plots static operating characteristics rapidly under conditions chosen by the operator. It also develops vacuum tube circuits quickly by means of pushbutton switching which allows electrodes to be inter-connected in any manner and to any of five voltage sources. Panel terminals allow insertion of components and special voltages so that circuits may be designed right on the instrument. The unit also performs transconductance, voltage, current, shorts, continuity, leakage and gas tests of JAN-1A and MIL-E-1B. Static operating conditions that can be plotted by Model 901A include transconductance vs. grid voltage or any other electrode voltage or current; plate voltage vs. plate current; grid voltage vs. plate current. Transconductance ranges are from zero to 50,000 micromhos with accuracy to five percent of full scale reading. The unit is self-contained, requiring no accessories. It measures 20 inches

wide by 18⅜ inches deep by 11½ inches high and weighs 75 pounds.

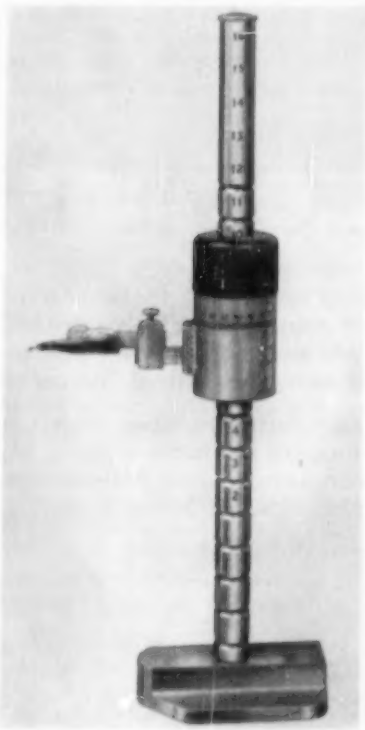
★ ★ ★

An improved line of refrigerated incubators which provide easier controls and more constant temperatures has been introduced by **Central Scientific Co.**, 1700 Irving Park Road, Chicago, Ill. Principal feature of the improved Cenco Refrigerated Incubator is the location of heating controls and dials. Mounted on the outside of the door, they enable operators to perform all adjustments without opening the door, thereby eliminating temperature fluctuations. Temperature from five degrees to 50 degrees Centigrade is controlled by a convenient dial at eye-level height. Also on the outside of the door is an easy-to-read dial thermometer which shows the exact inside temperature. A pilot light above the thermometer indicates when the unit is in operation. The incubator is thoroughly insulated and porcelain-enameled throughout. It will hold 120 bottles of 190-ml size or 105 bottles of 300-ml size. Additional storage space is provided by racks on the door. It meets the standard method requirements for the bacterial analysis of water and dairy products and the dissolved oxygen and biochemical oxygen demand in water, sewage, sewage effluent and industrial wastes. Price of the unit is $475.

★ ★ ★

A new portable lead testing comparator is now being produced by the **Jerpbak-Bayless Co.**, Solon Road, Solon, Ohio. The new comparator is quickly set to conform to the measurements of a master or precision screw and requires little or no experience for operation. Checking screws after heat treating, during the finish operation or at any time that the screw is in process is now a simple matter—even while on the machine. The gage also checks the amount of wear on machine tool lead screws without removing them from the machine. Builders and rebuilders of machine tools will find this instrument useful, as do the users of machine tools, for periodically checking the accuracy of the lead screw, elevating screw, etc. Precision lead screw manufacturers should find this comparator helpful in speeding production inspection schedules. The standard instrument is 12 inches in length. It has a measuring capacity of from ⅞ inch thread diameter to 2½ inches thread diameter in any pitch. The comparator is self aligning and inspection results are registered on a dial. Other size diameter and length gages may be obtained on special order to meet specification requirements.

★ ★ ★

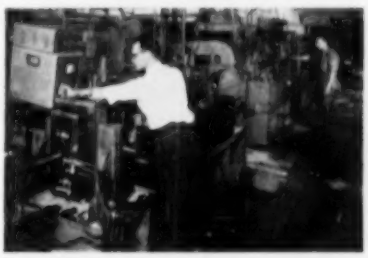


The Height Master height gage designed and manufactured by **Pacific Gage Co.**, 6501 Avalon Blvd., Los Angeles 3, Calif., is an independent, self-contained instrument which eliminates the need for gage blocks or transfer measuring equipment of

Sperry

ultrasonic inspection news

Automatic Inspection and Control on Continuous Production Line



Continuous inspection of steel tubing and strip at production speeds is now an accomplished fact with the new Sperry Ultrasonic Reflectoscope and RA attachment. This unit scans material traveling at high speeds and registers the presence of both internal and surface defects. Far more thorough than the human eye, it provides for both defect recording and signaling in addition to continuous inspection. Designed to incorporate signal lights or alarm bells, as well as automatic marking and machine cut-off units, the Sperry Reflectoscope and RA attachment is a flexible, accurate instrument which opens a new area to more effective cost-cutting quality control.

sperry products INC.
Danbury, Connecticut

I would like to keep posted on latest developments in ultrasonic inspection by industry. Put me on the list to receive Sperry's new Ultrasonic Inspection Newsletter.

Name_____
Title_____
Company_____
Address_____
City_____ Zone____ State_____

any kind. By loosening a torque screw it can be set to the desired inch and when the torque screw is tightened it is locked precisely. By turning the thimble, the desired hundredth is registered on the vertical scale and the desired thousandth lines up on the horizontal scale. Two models are presently ready — No. 1710 and 1705. Both have a range of measurement graduations from two to 17 inches. Model 1710 reads directly to 0.001 inches and is recommended for layout work and general inspection use. Model 1705 reads directly to 0.0005 inches. It is recommended for checking fixtures, drill jigs and for precision layout and inspection without use of any reference gages. Bases are 5¾ x 3¾ inches and the columns are stainless steel. The gage weighs 14 lbs. Accessories include an indicator extension arm, hardened tool steel scriber and an especially designed dial indicator.

* * *

NEW LITERATURE

Metron Instrument Co., 432 Lincoln St., Denver 3, Colo., have published Bulletin No. 200 describing the all-purpose Metron comparator gages for use in gaging external dimensions of parts having a variety of sizes and shapes. One model gages to ten millionths, 20 millionths, one ten-thousandth or two ten-thousandths of an inch. Two other models gage as little as ± one millionth of an inch or as much as ± 20 thousandths of an inch. Four ranges are provided in each of the three comparators available. Range calibrations are fixed and stable. No vacuum tubes, mechanical linkages or other limited-life components are used. These comparators have been manufactured by Metron since 1942. They were formerly distributed by the DoALL Company, but now are sold direct from the manufacturer.

A new 44-page book by Dr. F. H. Rolt, recognized authority in the fields of gaging and fine measurement, has been published by Hilger & Watts Limited. The author, now a consultant in metrology and standardization to some of England's leading instrument makers, was until 1953 superintendent of the metrology division, National Physical Laboratory—an institution comparable to our National Bureau of Standards. During this period, Dr. Rolt developed instrumentation, published numerous important articles and is known as the author of the standard work, *Gauges and Fine Measurement*. In his new book Dr. Rolt discusses interferometry as a method for measuring the length of gage blocks, using only the wave length of light as an absolute standard. Accuracy of determination is one millionth of an inch. The reviewing principles, as well as most existing English and German instrument designs, the book with graphs and illustrations thoroughly covers the entire subject. It refers in detail to latest developments and describes a new interferometer which accommodates at the same time up to 36 standard gage blocks wrung onto two steel platens. Gage blocks are tested in the same condition in which they are used, and flatness and parallelism are determined together with their length. This book, *Use of Light Waves for Controlling the Accuracy of Block Gages*, is available by writing to Engis Equipment Co., 431 South Dearborn St., Chicago 5, Ill.

A new specification sheet on the Liston-Becker Infra-red Analyzer Model 15A is now available from Beckman Instruments, Inc., Fullerton, Calif. The Liston-Becker Model 15A is a positive, non-dispersive instrument for the precise analysis of gases or liquids in complex streams. Its range of usefulness includes

WELCOME HOME!

To say "Welcome Home" to the American Society Quality Control instead of saying, "Welcome to Milwaukee," is no idle conceit. Surely, Milwaukee, with its century-old reputation for quality workmanship, is the logical "home" for the A.S.Q.C.

As acceptable tolerances have shrunk and as rule-of-thumb has given way to modern instrumentation. Milwaukee's industries have been in the vanguard. Thus, Milwaukee products have maintained their deserved reputation for quality.

We of the Milwaukee Brewers' Association are proud of our place as leaders in Quality Control. And we are proud that you have chosen Milwaukee as your headquarters. So we say, again, "Welcome Home!"

MILWAUKEE BREWERS' ASSOCIATION

A. Gettelman Brewing Company
Miller Brewing Company
Independent Milwaukee Brewery
Pabst Brewing Company
Jos. Schlitz Brewing Company

HOW "RAM" TEST HELPS PAINT A PICTURE OF STRESS AND STRAIN!

This is a portion of the loader framework under test. Note the maximum stress locations which were made visible through the use of a brittle lacquer coating.

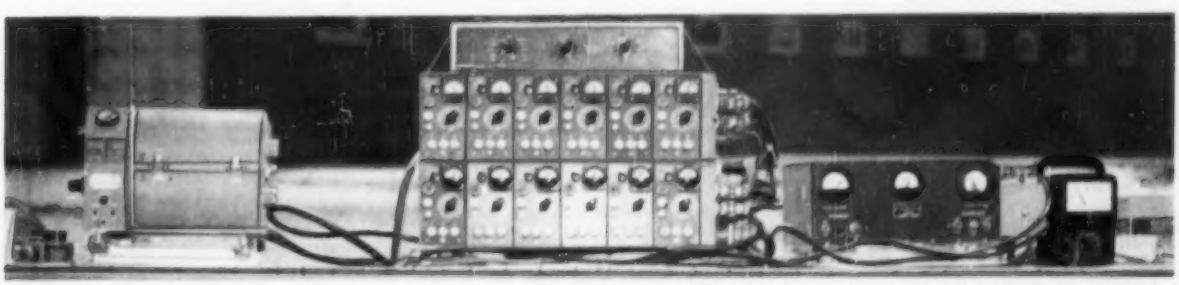
You're looking at a "ram" test in action.

It's used to check excessive stress on a loader attachment for IH's famous 300 Utility tractor. The resultant dynamic strains are measured by wire strain gages and are recorded by sensitive recording equipment.

The data is then analyzed and interpreted by our engineers. As a result, we are able to alter certain materials and manufacturing methods to be sure we maintain absolutely scientific quality control.

Tests such as these help hold our production costs down. Our quality standards are consistently maintained. At each step in this kind of quality control we obtain useful information that we will apply to future designs.

Quality control is a part of every Harvester product.



These are the sensitive dynamic strain recording instruments used in the field test of the Harvester loader. They record the tremendous shock strains occurring when the loader rams into the stony surface of the test ground.

INTERNATIONAL HARVESTER

analysis of gases or liquids in process streams, the detection and measurement of gases in biological and botanical studies and the analysis of various toxic industrial gases.

A new manual entitled "High Potential Dielectric Strength Testing with Hypot Juniors" is now available from Associated Research, Inc., 3758 West Belmont Ave., Chicago 18, Ill. Although written primarily around the use of Associated Research Hypot Junior instruments for this application, this 7-page manual also includes much information of a general nature on this subject, primarily applicable to the dielectric testing of small electrical components and equipment such as appliances, relays, switches, potentiometers, servo motors, pulse transformers, wiring harness, etc. Copies are free on request.

A new 8-page bulletin covering application of the ultrasonic Reflectoscope for non-destructive testing of products and equipment, has been published by Sperry Products, Inc., Danbury, Conn. The bulletin pictorially illustrates the many uses of the ultrasonic Reflectoscope and also explains in simplified terms the principle of ultrasonic inspection as well as illustrating the latest types of equipment available.

OUR EVER-GROWING FAMILY

With the addition of Waco and Memphis, the total number of sections of the Society is now 90. The Society is proud to extend a most cordial welcome to the new sections.

89—Waco (Dist. 4)

Chairman: Edwin F. Moore
Waco, Texas

Vice Chairman: Jack N. Peck
Mercury Tool & Machine Service
Waco, Texas

Secretary: Victor E. Paulos
Phillips Petroleum Co.
McGregor, Texas

Treasurer: Robert T. Kline
The General Tire & Rubber Co.
Waco, Texas

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Memphis, Tenn.

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Kimberly-Clark Corp.
Memphis, Tenn.

Treasurer: William W. Heiskell
Firestone Tire & Rubber Co.
Memphis, Tenn.

POSITIONS AVAILABLE

Address all replies to box number references to: American Society for Quality Control Room 6197 Plankinton Bldg., 161 W. Wisconsin Ave., Milwaukee, Wis.

PROCESS ENGINEER

Company located in northern Illinois has a position open for a Mechanical Engineer with 3-5 years experience. Duties will include the investigation of difficulties in the manufacture of small electro-mechanical devices. Experience in statistical planning and/or correlation of statistical data helpful. Must have the ability to work with people. Please reply to Box 12Y2 at the above address.

QUALITY CONTROL SUPERVISOR responsible for all plant statistical quality control services. Reports to plant manager. Requires basic knowledge of statistical quality control methods, ability to analyse raw material and finished product data. Knowledge of flexible packing materials such as paper and cellophane helpful. Salary $400-$500 per month. If interested reply with complete resume to Box 12Y3 at the above address.

MAY, 1956

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